Tourism Recreation Research and Education Centre

Lincoln University

Interactions Between Tourists and the Natural Environment:

Impacts of Tourist Trampling on Geothermal Vegetation and Tourist Experiences at Geothermal Sites in Rotorua

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Rotorua Case Study

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LINCOLN UNIVERSITY
Te Whare Wānaka O Aoraki

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Interactions Between Tourists and the Natural Environment: Impacts of Tourist Trampling on Geothermal Vegetation and Tourist Experiences at Geothermal Sites in Rotorua

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Summary

The main objection of this research was to evaluate tourist impacts on geothermal vegetation and to examine visitor's attitudes towards their impacts on vegetation.

Two commercially operated sites near Rotorua were selected for research and a controlled trampling experiment was carried out on another geothermal site. Changes in vegetation cover were assessed using archival photographs and a sequence of aerial photographs. Short transects were applied to informal tracks in order to assess vegetation characteristics. Interviews and observations were used to record tourist behaviour.

Overall the results show that the study sites provided a positive safe experience for visitors, which has minimal environmental effect. Geothermal vegetation is highly susceptible to trampling and the effects of trampling extend at least 30cm into the surrounding vegetation on either side of the tract. However, track management at the two sites appears to be adequate to ensure that there is only minimal damage to the surrounding vegetation.

Regeneration of geothermal vegetation is likely to be slow because of the low productivity of these species, particularly after track compaction, but high soil temperatures are unlikely to encourage the spread of week species into the surrounding vegetation.

Management of the study sites may need to consider visitor education. The sites studied in this research can be used as an example of how to achieve access to sites while at the same time protecting the environment.

Chapter 1

Introduction: Research Objectives and Study Area

1.1 Introduction

Rotorua, in New Zealand's North Island, has been a popular tourism destination since the late 1880s. Visitor numbers to Rotorua were estimated to be about 1.2 million in 1995/96, and are expected to increase in the future (PCE, 1997). The earth's crust is relatively thin around Rotorua, creating numerous geothermal sites in the area. These geothermal or "volcanic" features include bubbling mud pools, hot water lakes and streams, steam vents, and geysers that release hot water and steam in spectacular display on a regular basis. Not surprisingly, such natural attractions have long been the focus of much of the tourism to this region, and in the 1995/96 International Visitor Survey, geothermal sites were ranked as the main natural attraction for international visitors to geothermal areas.

As well as interesting geophysical features, the biology of geothermal sites is equally fascinating yet not widely appreciated (Huser, 1991; Ecroyd, 1982). Geothermal areas provide an extremely hot, humid, and acidic environment which most plants cannot tolerate. The species of plants that do grow in these types of areas are often rare; some are also endemic (Given, 1980; Burns, 1997). The Rotorua District contains almost all plant species associated with geothermal vegetation in New Zealand (Scott, 1992). Geothermal ecosystems also contain organisms thought to be amongst the oldest known, e.g., thermophilic archaebacteria (Potter, 1997). These ecosystems are uncommon both worldwide and nationally (Given, 1980). In addition to distinctiveness and rarity, these geothermal features and ecosystems can be extremely fragile (Huser, 1991).

There are several geothermal sites in the Rotorua District which people can visit. These include commercially operated sites that have visitors' facilities such as a café, souvenir shop and amenities and usually provide a map for visitors to partake in a self-guided experience. Other geothermal sites in the area have free access, and are managed by the Department of Conservation (DOC) or the District Council. Despite establishment of tracks in geothermal areas to limit visitor impact to defined areas, visitors move off-track to gain different views of particular features or to explore. This trampling damages geothermal vegetation, soils, and non-vegetated surrounds by breaking branches, killing plants, disturbing and compacting soils, and breaking up sinter[1] crusts. Tourist damage of geothermal ecosystems has been recognised in Japan (Glime and Iwatsuki, 1997) and in New Zealand (Given, 1976; Ecroyd, 1982; McMillan, 1982; Huser, 1991), however, there are no studies of its extent, impact, or the relative vulnerability of geothermal ecosystems to trampling.

[1] Siliceous or calcareous rock formed by deposit from springs.

The Department of Conservation has expressed concern over the impacts of visitors to geothermal sites, especially those where rare and unique geothermal vegetation grows. The Office of the Parliamentary Commissioner for the Environment (PCE) stated similar concerns in a report documenting the consultation of members of the local community, tourism industry and DOC about the impacts of tourism in the Rotorua District (PCE, 1997). A deficiency of information regarding the ecological impacts of visitors to geothermal sites was identified in the findings of the consultation. However, if decision-makers are concerned about environmental impacts as a whole, including their management, they will need to understand not only the ecological impacts of visitors, but also visitor perceptions of ecological impacts.

The trend for social tourism research in protected area management has been increasing over the past twenty years in a wide variety of fields (see for example OECD, 1980; Price, 1996), requiring managers to consider the needs and perceptions of the users along with the ecological characteristics of the site (Devlin, et al., 1995; Noe, Hammit and Bixler, 1997; Shelby, Vaske and Harris, 1988; Wight, 1998). It is imperative that decision-makers pay attention to understanding visitors' perceptions in order to make well-informed decisions which may affect public support of the area, especially since previous studies have already shown that users' perceptions invariably contrast with those of the management (Noe, et al., 1997; Shelby and Harris, 1985; Shelby, et al., 1988).

The present study aims to furnish decision-makers in the Rotorua region with information about ecological impacts of visitors and visitors' perceptions of ecological impacts to two key geothermal sites, and to provide information on management implications based on results from monitoring visitor use.

1.2 Aims and Objectives

Tourist impacts on geothermal ecosystems were evaluated, alongside a study to understand visitors' attitudes towards their impacts on the vegetation.

In particular, the research objectives were to determine:

- vegetation changes over time in relation to the history of tourist site development and use;
- the nature and extent of current unmanaged trampling impacts on vegetation;
- the sensitivity of geothermal vegetation to trampling; and
- to identify tourists' motivations for visiting the site
- describe tourists' perceptions of their effects on the vegetation, and
- describe tourists' behaviours at the sites.

1.3 Study Area

The study was conducted mainly at two commercially operated geothermal sites near Rotorua, namely: Waimangu Volcanic Valley and Waiotapu Thermal Wonderland. These sites were chosen for the unique geothermal vegetation contained within their boundaries, their commercial management regimes, and their popularity as a tourist destination. Both sites are approximately 20-25 minutes drive from Rotorua on the way to Taupo (Figure 1). It is not the purpose of this report to compare the two sites. Rather, the results are intended to be a description of visitor impacts on geothermal vegetation and visitor's impressions at commercially run geothermal sites in Rotorua. In addition, a controlled trampling experiment on geothermal vegetation was carried out at the Taheke geothermal area (Figure 1).

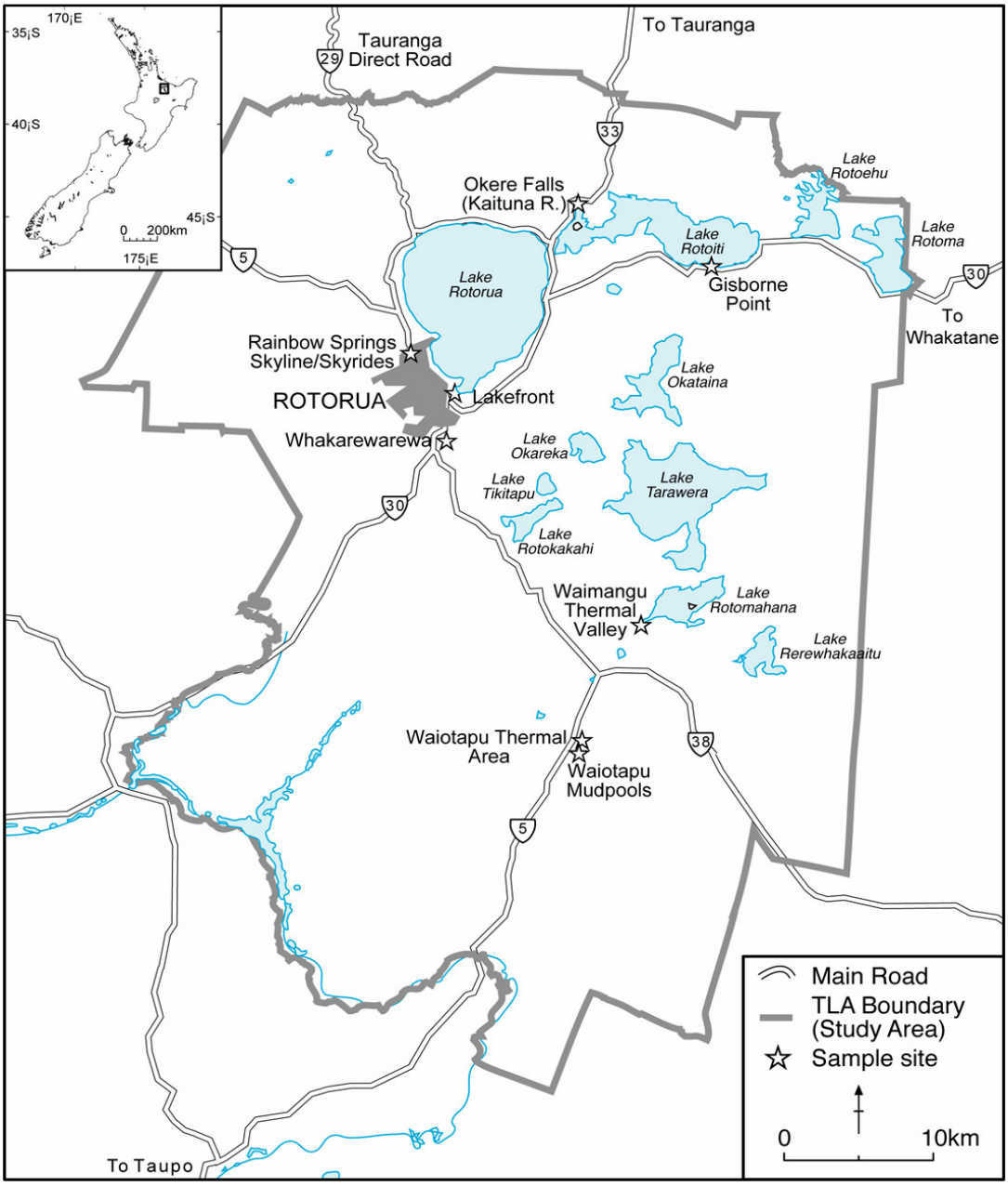

Figure 1
Map of Study Area Showing Major Attractions

1.3.1 Waimangu Volcanic Valley

'Waimangu Volcanic Valley' (map reference NZMS 260 U16 073187; Figure 2) occupies a valley southwest of Lake Rotomahana. Formerly famous for the Pink and White Terraces, the valley formed as a result of the eruption of Mount Tarawera in 1886 (Simmons, et al., 1993) which destroyed the well-known terraces but created a fissure allowing the escape of deep aquifers to the surface. All vegetation of the area was destroyed by ash at that time, so current vegetation has developed since then (Given, 1976).

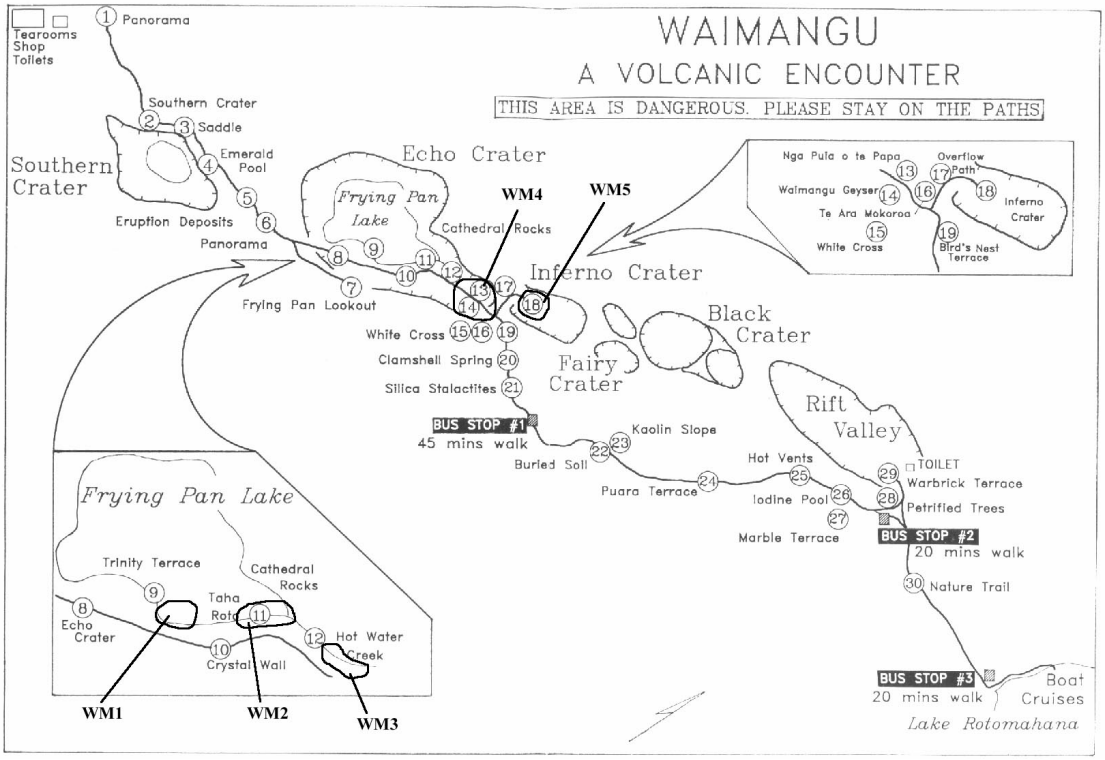

Figure 2
Map of Waimangu Volcanic Valley and Observation Sites
(Map reproduced with permission from the operator)

Maintained tracks lead tourists down the valley past a series of lakes (e.g., Echo Crater, Frying Pan Lake, Inferno Crater) filling explosion craters and along streams draining those lakes. These tracks encounter geothermal vegetation along the lake and stream edges. As well, visitors can catch a bus to any of three bus stops that provide access to the walking trails and the boat cruise on Lake Rotomahana. Most visitors walk down the valley and catch a bus back to the top where there is a souvenir shop and café.

Waimangu has been visited by tourists since late last century. One of the earliest attractions was the Waimangu Geyser, which was active between 1900 and 1904 (Seward and Sheppard, 1986). At that time it was the world's largest known geyser. Visitors were originally guided through the valley by Alfred Warbrick using the same route as is currently used. Visitor numbers have gradually increased over time (H. James, pers. comm.).

1.3.2 Waiotapu Thermal Wonderland

'Waiotapu Thermal Wonderland' (map reference NZMS 260 U16 045102; Figure 3) is a tourist concession of the Department of Conservation occupying an area of 40 ha within the 18km² Waiotapu geothermal field between Rotorua and Taupo (Hedenquist, 1986). Tourists are led past a zone of collapse craters with occasional sulphur deposits to a large sinter terrace, beside which is the Champagne Pool. This is a hot pool with a sinter rim occupying a hydrothermal eruption crater, which gains its name from the effervescence of CO_2 through its waters. Past the sinter terrace (Artist's Palette), tracks lead through a series of narrow canyons with coloured cliffs to Lakes Ngakoro and Whangioterangi which also occupy eruption craters.

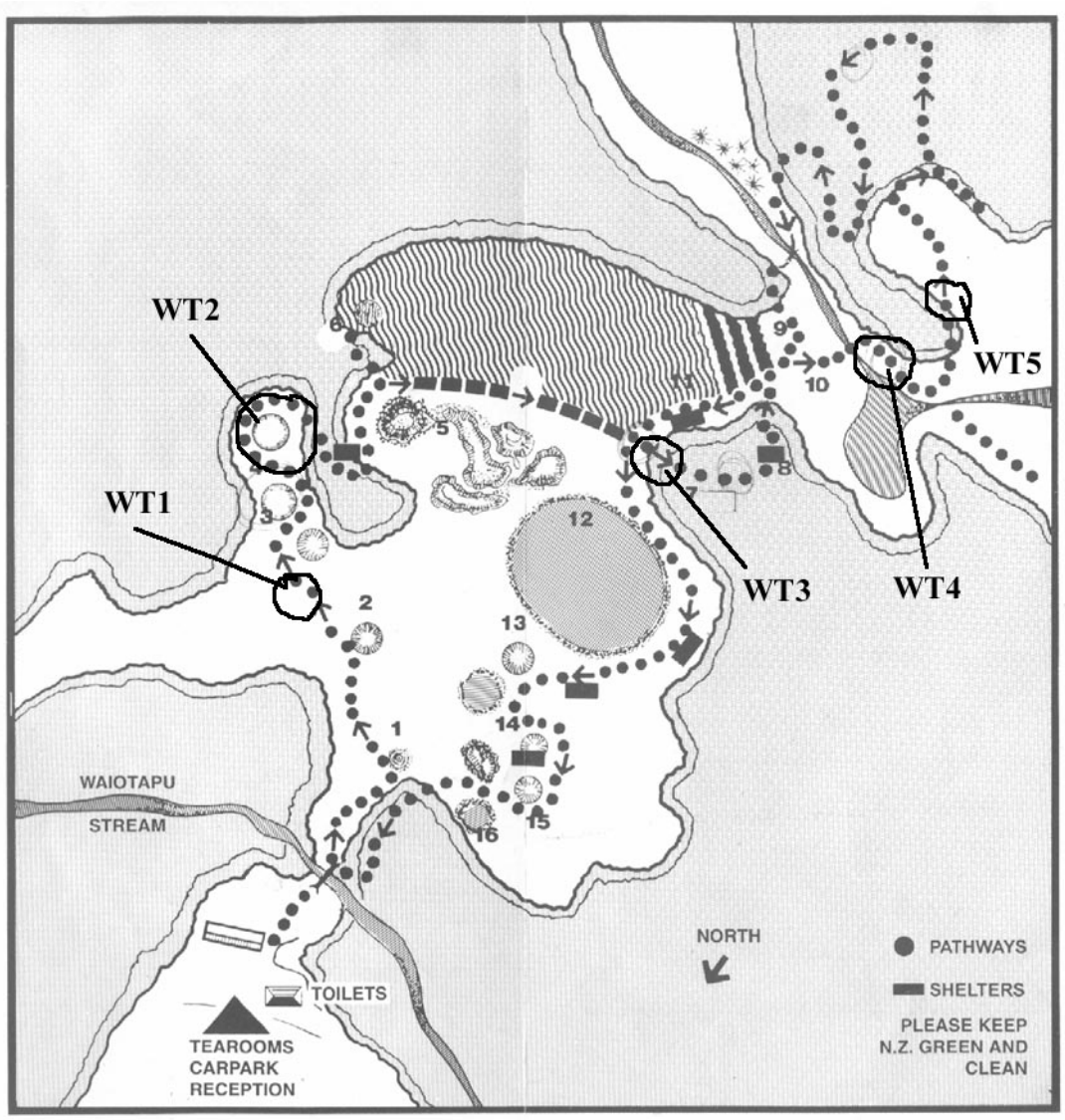

Figure 3
Map of Waiotapu Thermal Wonderland and Observation Sites
(Map reproduced with permission from the operator)

Waiotapu has been visited by tourists for more than a century. It became particularly popular following the Mount Tarawera eruption as a replacement attraction for the Pink and White Terraces which were destroyed. Tourist visits were largely uncontrolled until 1967 when a tourist concession was granted by the Department of Lands and Survey. Visitor numbers had reached 50,000 per year in 1982 (McMillan, 1982), and are now considerably higher (Alex Leinhart, pers. comm.). There has been some relocation of tracks over time particularly around the craters area (Figure 3).

Waiotapu provides maintained walkways throughout the site, giving access for visitors to view craters, terraces, pools, and geysers. The area is known for the many colours found in the earth throughout the site, caused by a wide variety of minerals in the water and soils. Associated with the operation is the Lady Knox Geyser, about 1.5km from the main entrance, which is "triggered" to erupt at a set time every day to guarantee visitors a view of the display. The operator also provides a café and souvenir shop at the entrance to the walkways. The paths at Waiotapu take visitors through a range of vegetation from colourful algae to prostrate kanuka and a short walk through a pine forest. The area which tourists visit has a larger proportion of non-vegetated area than that of Waimangu, due to the numerous craters, pools and terraces.

1.3.3 Taheke

The Taheke geothermal field occurs north of Rotorua (grid reference NZMS 260 U15 048497) on lands administered by Taheke Inc. Geothermal vegetation covers approximately 15 ha here, and is notable for the inland occurrence of pohutukawa forest surrounding the heated areas (Clarkson and Clarkson, 1992; Beadel, et al., 1996). Some of the geothermal areas have been previously mined for sulphur and/or silica, causing extensive modification of vegetation pattern (although this is recovering). There is no tourist access to Taheke geothermal areas.

1.4 Types of Vegetation at the Sites

The Waimangu geothermal reserve has the largest number of geothermally-associated plant species of any single location in New Zealand (Clarkson and Watt, 1986; Beadel, et al., 1996). Particularly notable is the diversity of unusual ferns and fern allies.

On steam-heated ground thermal vegetation is mostly prostrate kanuka shrubland. This is dominated by a 1-2m tall dense canopy of prostrate kanuka (*Kunzea ericoides* var. *microflora*), with occasional mingimingi (*Leucopogon fasciculatus*), and monoao *(Dracophyllum subulatum*), over a dense bryophyte turf groundcover. Common mosses and liverworts forming this turf are *Campylopus capillaceus* (endemic to geothermal areas), *C. introflexus, Isopterygium minutirameum, Lepidozia glaucophylla, and Lophocolea semiteres*. Around hot lakes, springs, and streams, populations of several thermal ferns occur, e.g., *Christella* sp. 'thermal', *Cyclosorus dentatus, Hypolepis dicksonioides, Nephrolepis* sp. 'thermal'. These are notable as occurrences of species that have their main centres of distribution in subtropical or tropical climates either in northern New Zealand or in the tropical Pacific. Also, *Cyclosorus dentatus* is listed as rare in the current New Zealand threatened and local plant list (Cameron, et al., 1995). Other unusual geothermally associated ferns or fern allies to occur at Waimangu are the living fossil, *Psilotum nudum*, characteristically found on clay banks*, Lycopodium cernuum, Dicranopteris linearis*, and *Cheilanthes humilis*. Hot springs and streams are also habitat for colourful mats of

geothermal cyanobacteria (blue-green algae), e.g., species of the genera *Chloroflexus, Mastigocladus,* and *Phormidium.*

Non-geothermal vegetation within Waimangu is generally secondary scrub and forest composed of kohuhu (*Pittosporum tenuifolium*), fivefinger (*Pseudopanax arboreus*), kamahi (*Weinmannia racemosa*), kanuka *(Kunzea ericoides)*, and wheki (*Dicksonia squarrosa*), with occasional areas of bracken (*Pteridium esculentum*), blackberry (*Rubus fruticosus*), and pines (*Pinus strobus* and *P. nigra*).

The vegetation of the Waiotapu Scenic Reserve, including the study area, has been described by Clarkson (1982), and Given (1995). In direct comparison with Waimangu, Waiotapu is notable for its low species diversity and has a surprisingly poor thermal flora, particularly in its main tourist area. Here, heated ground supports a scattered shrubland of mingimingi and prostrate kanuka over a groundcover dominated by lichens such as *Cladia aggregata* and *Cladon ia* spp. There is surprisingly little bryophyte turf development here compared with other geothermal areas. At the southern end of the Waiotapu, outside the tourist concession area, is a warm thermal swamp with small areas of the rare thermal swamp fern (*Cyclosorus interruptus*).

Non-geothermal vegetation surrounding the field is dominated by *Pinus radiata* plantations, and small areas of manuka (*Leptospermum scoparium*) scrub.

Thermal vegetation of the Taheke geothermal area is dominated by mingimingi (*Leucopogon fasciculatus*) and matata (*Histiopteris incisa*) scrub (Beadel, et al., 1996). However, small areas of prostrate kanuka – mingimingi shrubland with a bryophyte turf groundcover also occur. Of particular note, is the peripheral forest of pohutukawa (*Metrosideros excelsa*) and kamahi (*Weinmannia racemosa*), with pohutukawa having an unusual inland occurrence perhaps caused by the warmth provided by the hot springs (Clarkson and Clarkson, 1992). Non-geothermal vegetation of the Taheke area is predominantly gorse (*Ulex europaeus*) scrub and *Pinus radiata* plantations.

This report describes the impacts of tourist trampling on geothermal vegetation using historical photographs, track measurements and artificial trampling. At the same geothermal sites, tourists were observed and interviewed with regard to their opinions of the sites, their satisfaction with their visits, their impacts on the geothermal vegetation and awareness of their behaviour. The results are discussed and some conclusions are drawn with regard to tourist awareness and site management.

Chapter 2

Methods

2.1 Impacts of Tourist Trampling on Geothermal Vegetation

2.1.1 Vegetation History in Relation to Tourist Impact

Historical vegetation and track development at Waiotapu and Waimangu were assessed using two methods. First, archival photos of geothermal scenes or features from Waiotapu and Waimangu were re-photographed. Second, a chronosequence of aerial photos from the 1940s to the most recent (1997) were interpreted for temporal changes in vegetation cover and tourist tracks.

2.1.2 Current Trampling Impacts

We searched the track systems of Waiotapu and Waimangu for informal tracks leading through geothermal vegetation. For each informal track, we measured its total length, and its width and incised depth at regularly spaced positions along each track (4–7 positions depending on the length of the track). At regularly spaced intervals on each informal track and on the main managed tracks for comparability, we established short transects of three 1m x 0.3m plots; one in the track centre, one immediately adjacent to the track, and one in geothermal vegetation, 2m from the track edge. In each plot we recorded plant species present, their maximum height, and estimated their percentage cover over the plot. We also recorded soil temperature at 10cm depth (three replicates per plot) and soil penetration resistance using a manual penetrometer (five replicates per plot). Similar transects were completed at 3-4 locations on the main managed tracks for comparison.

2.1.3 Experimental Trampling

We investigated the relative vulnerability of geothermal vegetation to trampling by experimentally imposing different levels of trampling to vegetation not subject to previous trampling disturbance at the Taheke geothermal field. This site was chosen with the co-operation and assistance of the Department of Conservation and landowners. We followed the standard procedures of Cole and Bayfield (1993) so that our results will be comparable with previous studies in different vegetation types.

At Taheke, we identified areas of vegetation of similar composition to that encountered at Waimangu and Waiotapu. Within this vegetation type, we located 20 1.5m x 0.5m lanes with at least 0.4m buffer between each. Within each lane, we established a 1m x 0.3m plot in which we recorded plant species present, their maximum height, and estimated their percentage cover over the plot. We also recorded soil temperature at 10cm depth (three replicates per plot) and soil penetration resistance using a manual penetrometer (three replicates per plot).

Each lane was then randomly assigned one of five trampling treatments: control (no trampling), 25, 75, 200, and 500 passes and these were then applied to the lanes. Following this trampling, all plots within lanes were remeasured. The per cent change in relative vegetation cover was assessed by dividing the summed surviving cover on plots by the summed initial cover. This was calculated for shrub and groundcover tiers separately.

2.2 Observation of Tourist Behaviour

Four researchers were based at the two main sites (two researchers per site) for ten days to conduct interviews and make observations during January 1999, a peak visitation period. The tasks and sites assigned to each researcher were rotated to minimise individual biases and to provide variety in the work for the researchers. Throughout each day three 'runs' of observation work were performed in the field while continuous interviews with visitors were administered at the end of the walk. After the first observation run, the observer swapped tasks with the interviewer, then swapped again after the second observation run.

2.2.1 Observation Sites

At each site five observation points were chosen to record tourist behaviour (Figures 2 and 3). The operators provided information on areas they knew where visitors were likely to deviate off the formal path or damage vegetation in some way (by picking, trampling etc). The key factors in choosing each site were:

- evidence of human disturbance to vegetation (informal paths formed, damaged vegetation, etc);
- proximity to the formal pathway;
- proximity of attractive features (e.g., craters, sounds from a hidden source);
- ecological value of the vegetation surrounding the area;
- variety of ecologically valuable vegetation;
- variety of management tools at the site to control visitor behaviour (barriers, etc.).

Occasionally along the edge of the path were worn patches of grass which people may have used for photographic opportunities, rest stops, etc. As these patches were adjacent to the path and not encroaching on any of the vegetation (except for grass), these were included as part of the formal path for observation purposes.

2.2.2 Observation of Visitors

One of the two researchers at each site walked to each of the identified observation sites and recorded the movement and behaviour of visitors on the observation sheet (see Appendix 1) for ten minutes at each location. The observers were instructed to act as unobtrusively as possible and concealed the observation sheets in a copy of the guide map. Factors recorded on the sheet included the total number of visitors through the site, and information on any visitor seen deviating off the track or picking vegetation including:

- the size of the group they were in;
- whether people who went off the track went onto a non-vegetated area, brushed past plants, or trampled on vegetation (and a brief description of the type of vegetation they trampled);
- whether people who picked vegetation picked leaves, flowers, or other vegetation;
- the apparent reason for the behaviour (e.g., to take photos, smell leaves etc);
- the location at the observation site;
- the distance the visitor deviated off the path;

- whether the visitor was an adult or child;
- their gender;
- their approximate age;
- whether they spoke English (if the observer could hear them or see which language their guide map was in);
- the number of the voucher they were given, if any (see below).

A method was tested for interviewing people who were observed going off the path or picking vegetation. This was developed to try to measure the proportion of visitors who were honest in the survey questions about their behaviour at the site. These visitors were approached by the observer and asked if they would mind participating in the study by completing a survey at the end of their walk. They were handed a coded voucher that entitled them to a complimentary tea or coffee if they handed it in to the interviewer based at the café. The code on the voucher informed the interviewer what type of behaviour the respondent was observed doing, and which location they were observed at. This method was not practical at these sites since they were usually quite busy, making it impossible for the observer to record everyone as well as approach people with the vouchers. In all, only seven vouchers were distributed and this component of the study was abandoned.

2.3 Interviews with Visitors

At the completion of the visit, the guests had to walk through a souvenir shop and café at both sites. This enabled the interviewers to observe visitors leaving the walkway and select them at random. The selection process differed slightly for each site.

At Waimangu, most visitors were brought back to the shop by the bus. This meant there were only about nine opportunities throughout the day to select people to interview. The interviewer counted the number of people coming off the bus, and selected the person who corresponded to a pre-chosen random number between one and six. Since the bus was not always full, the range of random numbers was kept to a minimum. If the person refused to participate, the refusal was noted and the next person to pass the interviewer was chosen.

Waiotapu was easier to sample as there was a more constant flow of visitors leaving the walkway. After each interview, the interviewer used the next-to-pass principal to select the next participant. At both sites it was extremely difficult to survey visitors who were on bus tours. These groups usually had strict time restraints on their visit and while every effort was made to interview people on tours, it was not always possible to do so.

Interviewees at both sites were offered a cup of tea or coffee. The interview was structured and involved an interviewer-administered questionnaire (see Appendix 2). The questionnaire contained mainly open-ended questions to allow for detailed responses and a few closed-ended questions to enable comparisons between the present study, previous studies by the same research team and other concurrent studies in Rotorua. Likert scales (Smith, 1989) were used on four questions. A copy of the questionnaire was placed in front of the participant to assist in comprehension of the questions and rating scales. As there were many German visitors to the sites, some of the more difficult words were translated and kept in the interviewers' notebook to show participants when it was necessary. Instructions for the interviewers were printed on each questionnaire and the researchers undertook comprehensive training and site familiarisation prior to the commencement of the fieldwork. In total 336 visitors were interviewed in this manner.

2.4 Data Analysis

2.4.1 Coding of Open-Ended Questions

Open-ended responses were coded to analyse the answers provided by participants. Inter-coder reliability checks were run between two coders, and a high level of agreement (>99%, Singleton, et al., 1988) was achieved after discussion and clarification of the categories between the coders. During the coding process, multiple responses to the questions were permitted to ensure all topics mentioned by the respondents were included, and to allow for more than one response to questions that did not require an order of importance of responses.

2.4.2 Comparisons Between 'Deviators' (those who admitted to inappropriate behaviour) and the Rest of the Sample

The sample of respondents was divided into two groups: those who said they behaved inappropriately (by going off the path or picking vegetation) and those who said they did not go off the path or pick vegetation. Tests for significant differences between the two groups were performed using the Pearson chi-square (χ^2) test (Bryman and Cramer, 1997). The number of categories in the age groups variable was collapsed to allow for the minimum number of cases (five) in each category. The following age groups were used for the chi-square analysis:

Group 1: 15-24 years
Group 2: 25-34 years
Group 3: 35-44 years
Group 4: 45-54 years
Group 5: 55+ years

Chapter 3

Results

3.1 Vegetation History in Relation to Tourist Impact

Site matches were made of 17 of 57 archival photos found, and these were rephotographed. The earliest of these was 1894 but the majority ranged from the 1930s to the 1960s. Both Waimangu and Waiotapu were largely unvegetated at the beginning of the century, Waimangu a result of the Tarawera eruption. The photos confirm that large numbers of tourists have been visiting these sites for the last century (Plate 2A). The sequence of photos shows non-geothermal vegetation surrounding the main geothermal features to have grown from almost nothing, to scrub, and now, to forest (Plate 1A, B, Plate 3A, B, C). There has been little change to the features themselves nor to any areas of geothermal vegetation that were part of the photos (Plate 1A, B, Plate 2A, B, Plate 6A, B). However, the photos particularly identified the development of unmanaged tracks around a lookout at Waimangu (Plate 3B, C), and partial burial of geothermal features (e.g., the Warbrick Terrace at Waimangu, Plate 4 A, B) by sediment build-up in a stream bed (possibly a result of inadequate culverting of the stream beneath a tourist road built downstream).

The chronosequence of aerial photos confirms the marked increase in height and cover of adjacent non-geothermal vegetation (Plate 5A, B). Over the last 50 years, the tracks exploring these attractions have decreased in number but those remaining have increased in width. The central crater area at Waiotapu is notable as it has remained virtually devoid of vegetation in contrast to the regrowth nearby (Plate 6A, B).

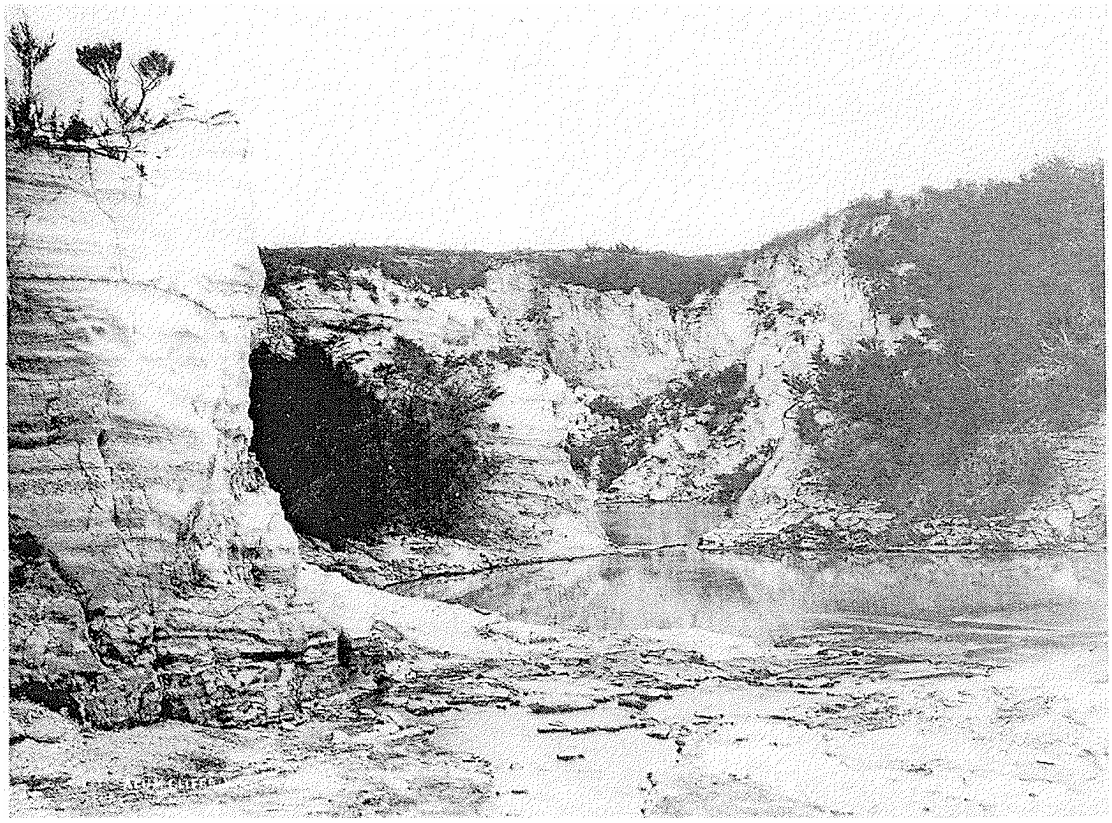

Plate 1A
Alum Cliffs, Waiotapu, 1897 (Source: Rotorua Museum)

Plate 1B
Alum Cliffs, Waiotapu, 1999 (Source: Bruce Burns)

Note growth of non-geothermal scrub and pine forest above cliffs

Plate 2A
Artist's Palette, Waiotapu, 1971 (Source: Weekly News, August 16, 1971)

Plate 2B
Artist's Palette, Waiotapu, 1999 (Source: Bruce Burns)

Plate 3A
Frying Pan Lake, Waimangu, pre 1930
(Source: Cowan, 1938)

Plate 3B
Frying Pan Lake, Waimangu, circa 1970
(Source: Rotorua Museum)

Plate 3C
Frying Pan Lake, Waimangu, 1999
(Source: Bruce Burns)

Note deterioration of geothermal vegetation between (B) and (C) on hill slope below lookout, centre right of photo. Note person exploring off-track in (B).

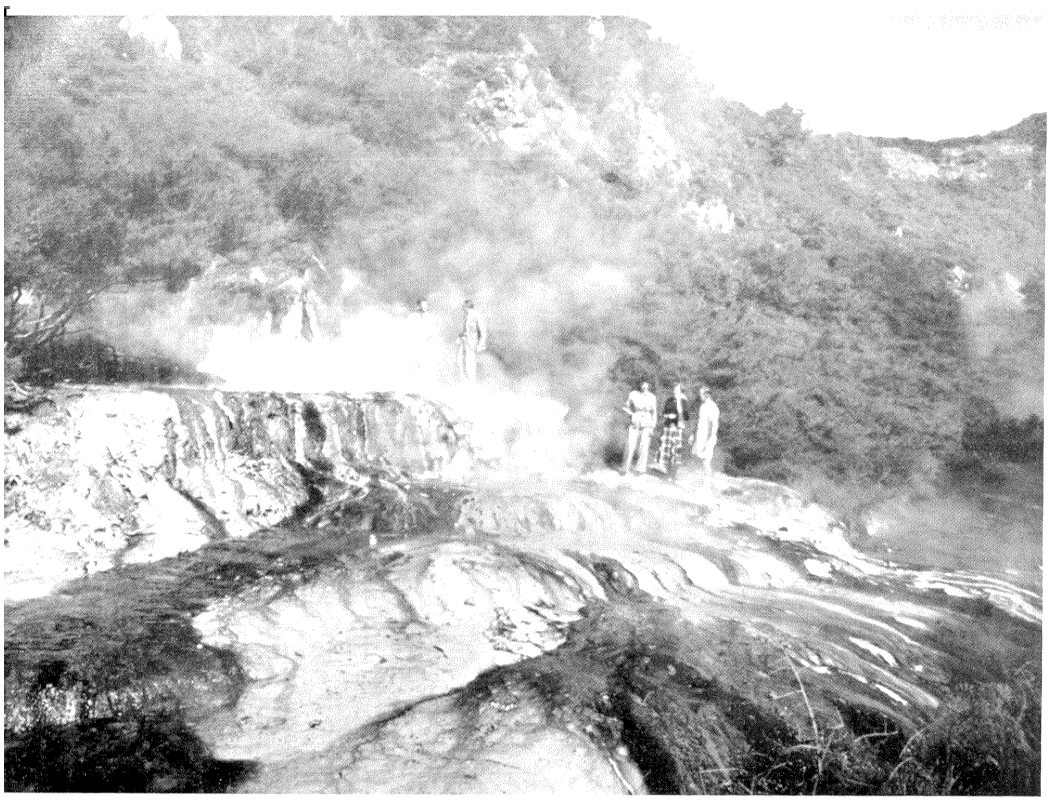

Plate 4A
Warbrick Terrace, Waimangu, 1954 (Source: Seaward 1954)

Plate 4B
Warbrick Terrace, Waimangu, 1999 (Source: Bruce Burns)

Note lower part of terrace now buried by sediment

Plate 5A
Overview of Main Crater, Waiotapu, pre 1920 (Source: Rotorua Museum)
Taken from site of original accommodation house

Plate 5B
Overview of Main Crater, Waiotapu, 1999 (Source: Bruce Burns)

Note increase in both geothermal and non-geothermal vegetation

Plate 6A
Devil's Home, Waiotapu, circa 1960 (Source: Rotorua Museum)

Plate 6B
Devil's Home, Waiotapu, 1999 (Source: Bruce Burns)

Note similarity of patches of geothermal vegetation behind crater

3.2 Trampling Impacts

3.2.1 Current Trampling Impacts

Four informal tracks were sampled at Waiotapu and five at Waimangu (e.g., Plate 7). The total length of informal tracks measured was 78m at Waiotapu and 218m at Waimangu. These tracks were 0.3-2.6m wide (mean: 1.54m at Waiotapu and 0.69m at Waimangu) and incised to an average depth of 3.5cm compared with adjacent ground levels. Generally, incision of tracks had removed the thin humus and A horizons present, leaving a consolidated pavement (e.g., Plate 8). The main tracks at Waiotapu were sampled in four locations (e.g., Plate 9) and three at Waimangu. Main tracks were 2.0-2.9m wide at Waiotapu (mean: 2.6m) and 1.8-2.7m wide at Waimangu (mean: 2.3m).

Plate 7
Example of Informal (unmanaged) Track at Waimangu
(Source: Bruce Burns)

Plate 8
Erosion of Topsoil by Trampling at Waiotapu
(Source: Bruce Burns)

Plate 9
Example of Main (managed) Track at Waiotapu
(Source: Bruce Burns)

Soils at the centre of tracks showed significantly higher penetration resistance than at edges or 2m distant from tracks at both Waiotapu and Waimangu (ANOVA, $P<0.001$, Figure 4 and 5). At Waimangu, informal tracks had significantly lower penetration resistance than main tracks (ANOVA, $P<0.001$). However, at Waiotapu, informal tracks were not significantly different in their level of compaction from the main tracks (Figure 5). Informal tracks at Waiotapu were more compacted than at Waimangu.

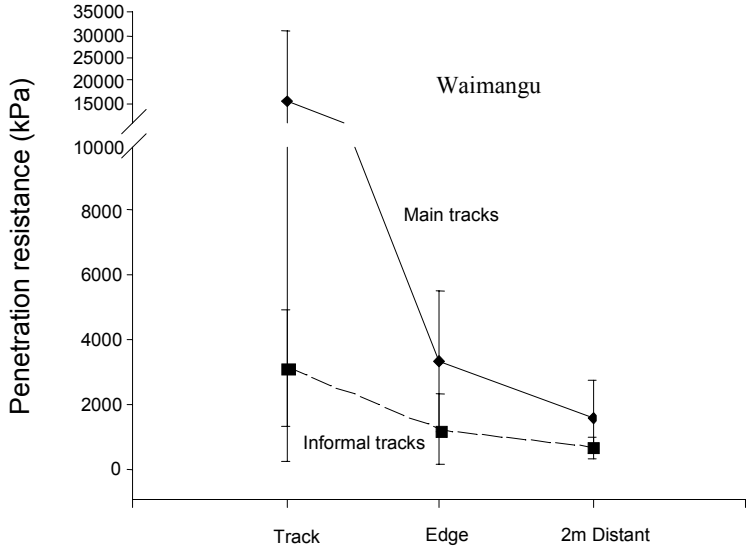

Figure 4
Soil Penetration Resistance of Tracks, Edges, and Positions 2m Distance From Tracks for Main and Informal Track Types at Waimangu Geothermal Attraction

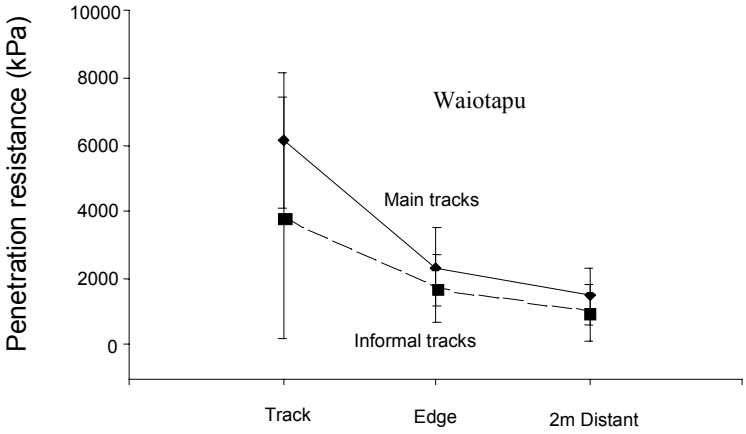

Figure 5
Soil Penetration Resistance of Tracks, Edges, and Positions 2m Distance From Tracks for Main and Informal Track Types at Waiotapu Geothermal Attraction

At Waimangu, soil temperatures at 10cm depth of informal tracks were much higher than the temperatures of main tracks (Figure 6 and 8). Informal tracks traversed areas with soil temperatures averaging 60°C, with a maximum at 100°C, compared with the main tracks where soil temperatures averaged 30°C. All tracks at Waiotapu occurred on soils with 10cm temperatures between 20 and 30°C (Figure 7 and 9).

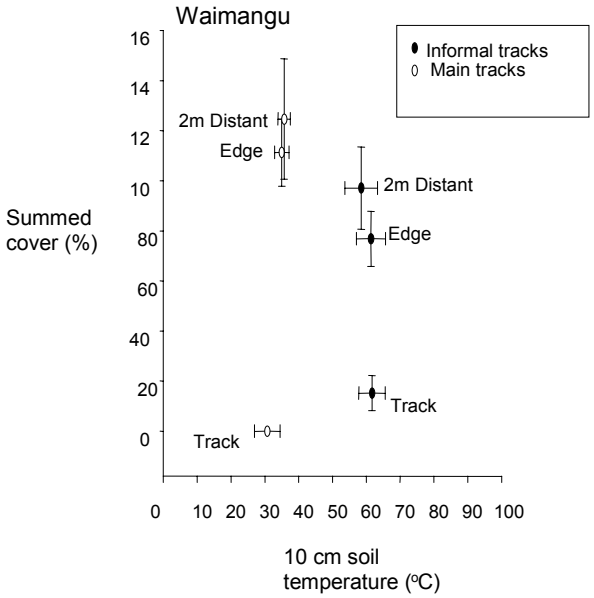

Figure 6
Means Standard Errors of Summed Vegetation Cover by 10cm Soil Temperatures for Replicate Plots Located on, Immediately Adjacent to the Edge, and 2m Distance from the Edge of Informal (unmanaged) and Main (managed) Tracks at Waimangu Geothermal Area

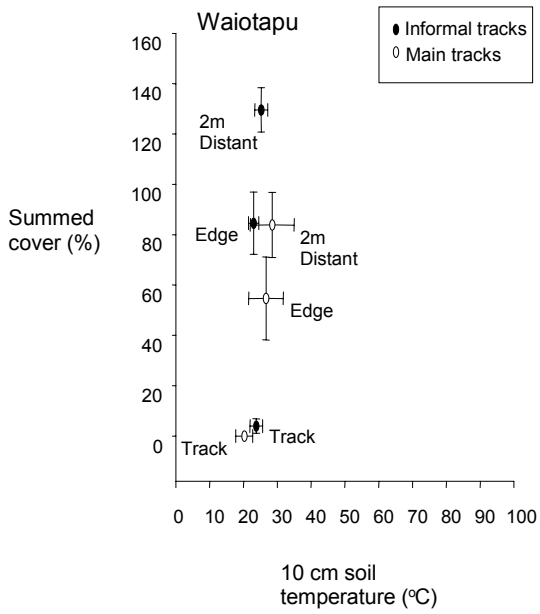

Figure 7
Means Standard Errors of Summed Vegetation Cover by 10cm Soil Temperatures for Replicate Plots Located on, Immediately Adjacent to the Edge, and 2m Distance from the Edge of Informal (unmanaged) and Main (managed) Tracks at Waiotapu Geothermal Area

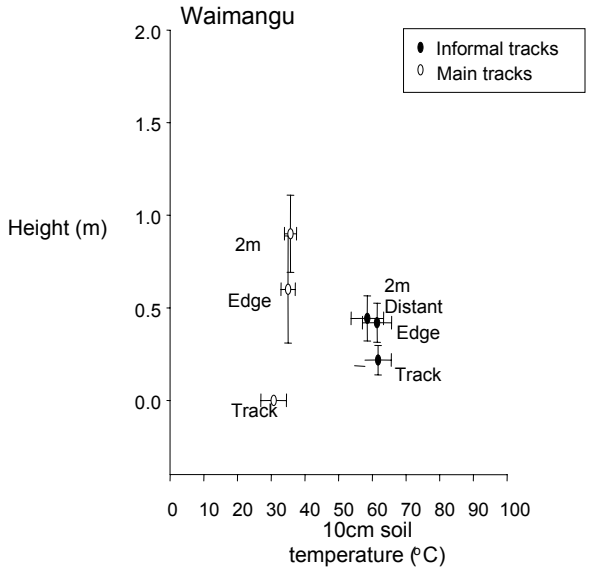

Figure 8
Means Standard Errors of Maximum Vegetation Height by 10cm Soil Temperatures for Replicate Plots Located on, Immediately Adjacent to the Edge, and 2m Distance from the Edge of Informal (unmanaged) and Main (managed) Tracks at Waimangu Geothermal Area

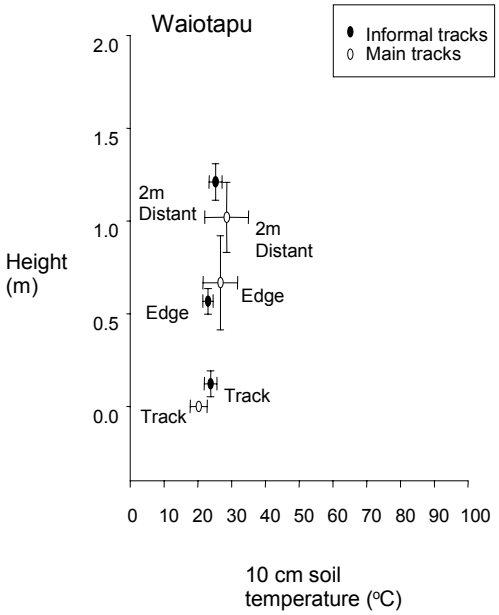

Figure 9
Means Standard Errors of Maximum Vegetation Height by 10cm Soil Temperatures for Replicate Plots Located on, Immediately Adjacent to the Edge, and 2m Distance from the Edge of Informal (unmanaged) and Main (managed) Tracks at Waiotapu Geothermal Area

Within sample plots measured at Waimangu, geothermal vegetation was dominated by 0.5-1m tall prostrate kanuka (*Kunzea ericoides* var. *microflora*) with occasional monoao (*Dracophyllum subulatum*), over a groundcover of mosses and liverworts including *Campylopus capillaceus*, *C. introflexus*, *Dicranum robustum*, and *Lophocolea semiteres*. Exceptions to this composition at Waimangu were edge plots on the main tracks where we also found several adventive grasses and weeds (i.e*., Paspalum dilatatum, Eragrostis benthamii, Cynosurus cristatus, Lotus pedunculatus*). Vegetation encountered at the main crater area of Waiotapu consisted of a 0.5-1.4m tall shrubland of mingimingi (*Leucopogon fasciculatus*) and prostrate kanuka over a groundcover of the lichens *Cladia aggregata*, and *Cladonia* spp.

At both Waimangu and Waiotapu, vegetation cover and height on track edges were significantly lower than 2m distant from the track (Figures 6, 7, 8, and 9). There was negligible vegetation cover and height recorded on both informal and main tracks at both sites. At Waimangu, vegetation cover and height adjacent to informal tracks was generally lower than that adjacent to main tracks. This is probably a result of the higher soil temperatures occurring adjacent to the informal tracks here.

3.2.2 Experimental Trampling

Vegetation of the plots was dominated by a shrub tier of 0.5-2m tall prostrate kanuka with occasional mingimingi over a groundcover of geothermal bryophytes including *Campylopus capillaceus*, *C. introflexus*, *Telaranea praenitens*, and *Lepidozia glaucophylla*. Soil temperatures at 10cm depth recorded in the plots had a mean of 32°C and a range of 16 to 54°C. As at the other study sites, height of the shrub tier decreased as soil temperatures increased.

Penetration resistances of soils increased rapidly as trampling intensity increased up to 200 passes and then increased more slowly up to 500 passes (Plate 10A, B, Plate 11A, B, Figure 10). After 500 passes, penetration resistance of soils had reached approximately 2000kPa. The mean penetration resistances of informal tracks at Waimangu and Waiotapu (Figure 4 and 5) were even higher than this (3-4000kPa) suggesting these tracks had been used substantially more than 500 passes. Relative vegetation cover of lanes also changed rapidly with trampling, decreasing substantially to <20 per cent after 500 passes (Figure 11). However, comparison of decreases in relative cover for groundcover versus shrub tiers shows that the bryophyte groundcover is reduced much more quickly by trampling than the shrub tier and is largely removed after only 75 passes (Figure 12).

Plate 10A
Geothermal Vegetation at Taheke Before and After Experimental Trampling
Before 25 Passes
(Source: Bruce Burns)

Plate 10B
Geothermal Vegetation at Taheke Before and After Experimental Trampling
After 25 Passes
(Source: Bruce Burns)

Plate 11A
Geothermal Vegetation at Taheke Before and After Experimental Trampling
Before 500 Passes
(Source: Bruce Burns)

Plate 11B
Geothermal Vegetation at Taheke Before and After Experimental Trampling
After 500 Passes
(Source: Bruce Burns)

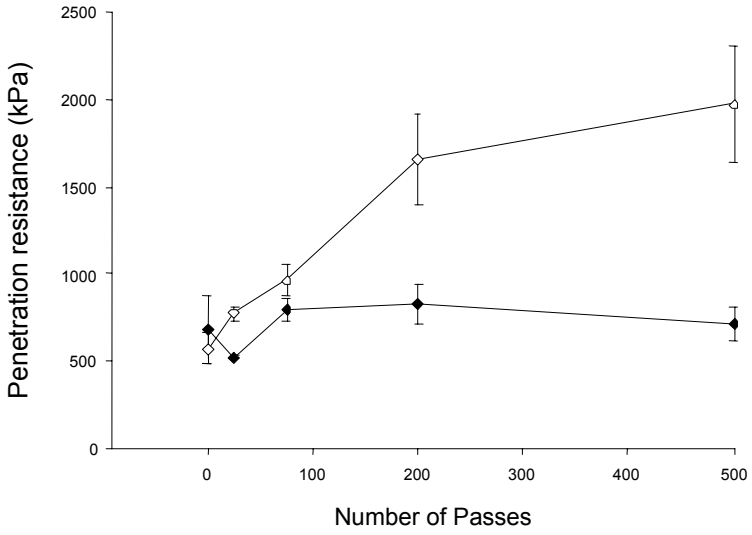

Figure 10
Changes in Soil Penetration Resistance in Geothermal Vegetation Subject to Different Trampling Intensities. Each Point represents the Mean of 4 Replicate Lanes ± 1 Standard Error. Dark Circles are Values Before Trampling and Open Circles are Values After Trampling

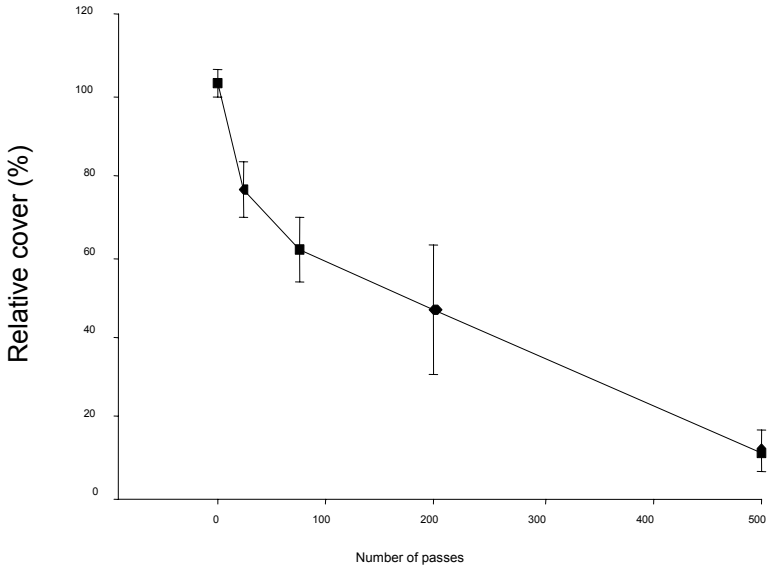

Figure 11
Relative Cover of Vegetation After Different Trampling Intensities at Taheke Geothermal Area

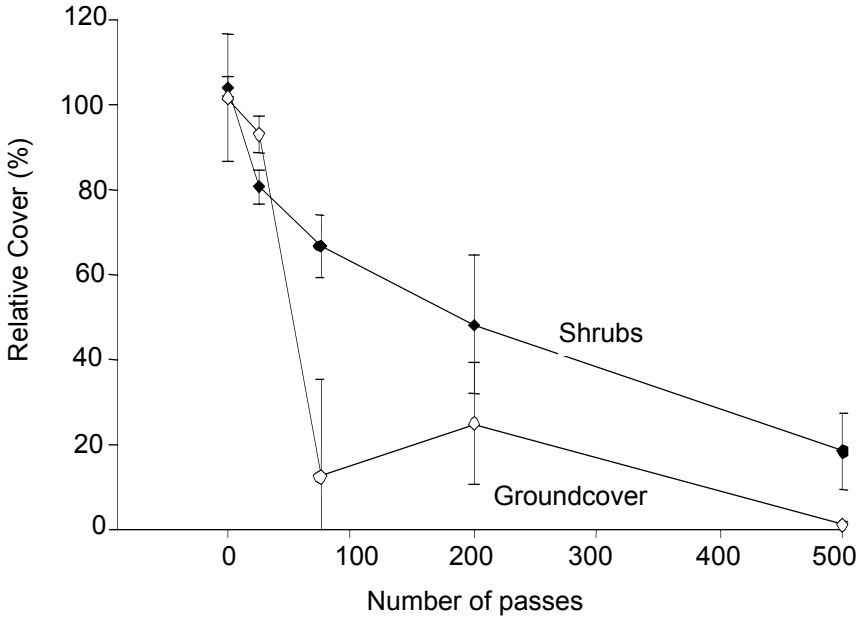

Figure 12
Relative Cover of Shrubs and Groundcover Bryophytes after different Trampling Intensities at Taheke Geothermal Area

3.3 Tourist Behaviour

3.3.1 Visitor Demographics and Characteristics

The data presented below originate from the 336 visitors interviewed at Waimangu and Waiotapu thermal areas during the month of January 1999. For details of sampling procedures, readers are referred to Chapter 2 of this report.

3.3.2 Country of Origin

Comparative data on country of origin of the visitors were only available from one of the operators. The sample figures generally corresponded well (within 2%) with data collected by the operator over the same period. The exceptions to this were European countries (grouped) being under-represented in the sample by approximately 7 per cent, and UK countries were over-represented by 3 per cent. Asian countries were also under-represented in the sample, however the actual percentage of Asian visitors was relatively low (less than 5%). These differences may reflect some language difficulties experienced in the field. Also, as mentioned before, tour groups were also difficult to survey and Asians tend to travel in tour groups. Over 57 per cent of the survey sample were from the UK, New Zealand and Australia (see Table A1 in Appendix 3)[1].

[1] For ease of reading only key results are presented in the text. Full data from visitor surveys are presented in Appendix 3, with Table references indicated by the prefix 'A'.

3.3.3 Group Size and Group Type

The types of groups visiting the geothermal sites were generally families and couples travelling in small groups. Most of the respondents (87.3%) were in a group size of four or less people (Table A2). Over a third of the sample was travelling with their partners or spouses, and an additional quarter of the respondents were visiting with their family (Table A3).

3.3.4 Gender and Age

The sample of respondents was divided equally in terms of gender (Table A4). Figure 10 indicates there was a bimodal spread of respondents in the various age groups, however there was good distribution throughout the categories overall. People in the mid to late 20s group represented the largest group (17.0%) in the survey, followed by people in the 30-34 years group (12.5%). The third largest group was people in their early 50s (11.6%).

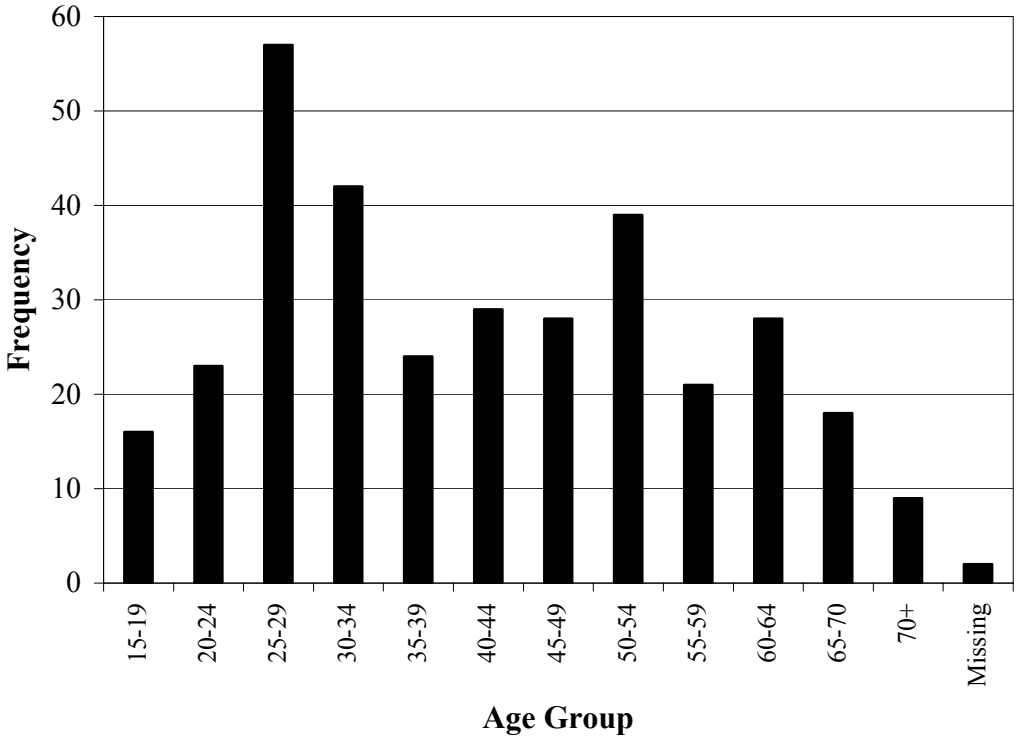

Figure 13
Age Groups of Respondents

3.3.5 Visitors General Attitude Towards, and Interaction With, the Environment Worldwide

When asked about their level of concern about the environment in general (not just the geothermal environment, but the environment worldwide) the sample of visitors indicated they had a moderate to strong level of concern overall (Table 1). However as Table A5 indicates this level of concern does not necessarily translate into membership of environmental groups (17.3% membership).

Table 1
Overall Attitude Towards the Environment

Response	Frequency	%	Mean	Std dev
Not at all concerned	8	2.4		
Slightly concerned	14	4.2		
Moderately concerned	88	26.2		
Very much concerned	154	45.8	3.72[1]	0.88
Extremely concerned	52	15.5		
Missing	20	6.0		
Total	336	100.0		

Note: 1. Based on a 5 point scale where 1 = not at all concerned and 5 = extremely concerned

Most of the respondents (82.1%) said they participate in some sort of outdoor activity on a regular basis (Table A6). However, these activities varied greatly from gardening to mountaineering and were not able to be analysed further since there was a lack of information on the outdoor activities participated in by many of the participants.

3.3.6 Visitors' Motivation and Experience with Geothermal Sites

When asked "What was your main reason for visiting this attraction today?", visitors gave a range of answers which were coded into the categories shown in Table A7. Not surprisingly, the most common reason was that they wanted to see geothermal sites with nearly 40 per cent of overall responses falling into this category. However, when international visitors are considered as a separate group, this category rises to almost 50 per cent. Comments about "sightseeing/just passing by" amounted to 21 per cent of the overall comments. The third most common theme (13.6%) was "to show others", but this motivation was by far the most important for New Zealand domestic visitors.

Visitors were asked how important visiting a geothermal site was to them during their stay in the Rotorua area. Many visitors (41.7%) considered a visit to a geothermal site to be at least an important part of their holiday to Rotorua, with nearly half of the sample (49.4%) indicating that it was their main reason for visiting Rotorua (Table A8).

The sample had a reasonably high level of previous experience but low frequency of visitation to other geothermal sites. The proportion of the sample which said they had previously visited geothermal sites (including sites overseas) came to nearly 60 per cent (Table A9).

As was expected, most of the people (91.5%) who had previous experience at geothermal sites only visit a few in their entire lifetime (Table A10). Monthly, or even annual visits are rare.

Most visitors (72.9%) to the geothermal sites ventured through the entire site (Table A11) stating that they travelled to the end of the paths or roads at the site they visited.

3.4 Visitor Attitudes in General

3.4.1 Satisfaction with the Visit Overall

The geothermal sites received a high overall rating in terms of visitors' satisfaction (Table A12). Sixty-five percent reported being very satisfied and 32.4 percent satisfied with their visit. On a five point satisfaction scale where 1 = very dissatisfied and 5 = very satisfied, the mean rating was 4.62 with a standard deviation of 0.56, indicating that visitors were overall well satisfied with their visit.

3.4.2 Satisfaction with the Physical Structures for Visitor Management

When asked about the physical management structures in place, the sample of visitors indicated that they were most satisfied with the walkways (Table 2). While satisfaction was slightly lower for the barriers and signs, the means for these two items indicate that visitors were largely satisfied (scale point 4) or very satisfied (scale point 5).

Table 2
Satisfaction with Structures

Structure	Mean[1]	Std dev	Frequency	Missing
Walkways	4.43	.67	335	1
Barriers	4.22	.82	333	3
Signs	4.20	.76	332	4

Note: 1. Based on a 5 point scale where 1 = very dissatisfied, and 5 = very satisfied

3.4.3 Personal Feelings of Danger and Risk

Despite the thinness of the earth's crust in the Rotorua area, and the scalding temperatures of the water in some pools and streams, most of the visitors (over 91%) felt safe walking around the geothermal sites (Table A13). Respondents were probed with further questions about why they felt safe or unsafe. The management regime of the site features in over 40 per cent the visitors' comments about feeling secure in the site (Table A14). While there were only relatively few (6.5%) people who said they felt there was some danger or risk, they were mostly concerned about natural dangers such as steam, fumes and hot water (52% of respondents) (Table A15). Interestingly, only 3 of the 23 people who said they *did* feel some element of danger to their health or safety indicated that they went off the path during their visit.

3.5 Visitor Attitudes to the Environment

3.5.1 Importance of Natural Features and Awareness of Vegetation

As would be expected, visible geothermal activity was ranked as the most important natural feature to the visitors ' experience at the site (Table 3). Vegetation did not feature strongly as an important part of the respondents' experiences, however it was rated higher than wildlife. This is not surprising given that there is little wildlife to be seen in these areas, although the nearby lakes are home to a variety of bird life which are usually visible from parts of the track near the far end of both sites.

Table 3
Importance of Natural Features[1]

Natural Feature	Mean	Std. Dev	Mode	Frequency	Missing
Visible geothermal activity	1.39	0.80	1	335	1
Evidence of past geothermal activity	2.39	0.98	2	334	2
Waterways	2.93	1.04	3	335	1
Vegetation	3.64	0.90	4	335	1
Wildlife	4.64	0.73	5	334	2

Note: 1. Respondents ranked each item from 1 to 5 where 1 = the most important, 5 = the least important

A surprisingly high proportion (nearly two thirds) of respondents said they did not know that there were rare and unique plants growing in the area of the site they were visiting (Table 4). This was despite the fact that there was information about the uniqueness (and need for protection) of the vegetation in the brochures and signs at each site.

Table 4
Awareness of Rare and Unique Plants Growing in the Area

	Frequency	%
No	221	65.8
Yes	110	32.7
Missing	5	1.5
Total	**336**	**100.0**

For those who were aware of the unique flora, the most effective way of informing visitors about it appeared to be through the brochure, with a slightly little more than 30 per cent of the respondents indicating that this was where they learnt about the vegetation. Books also featured as a common reference (Table A16).

3.5.2 Visitor Impacts in General

The respondents were asked if they thought that visitors to the sites had any impacts on the vegetation. Interestingly, nearly two thirds of the visitors surveyed said they thought there were no impacts on the vegetation (Table A17).

The one quarter of respondents who answered ‘yes’ in the question above (n=83 of 336) were then asked what sort of impacts they thought were occurring. While many comments were not specific about the type of impact, approximately one third of the participants mentioned trampling, picking, and erosion impacts (Table 5). More than a quarter of the comments were conditional statements such as “if they go off the track”, and “if tourist numbers increase there could be a problem”.

Table 5
Types of Impacts Respondents Think Visitors Have on the Vegetation

Impact Theme	Frequency[1]	%
Impacts depend on behaviour – *responses to do with visitor behaviour, such as "as long as they stay on the paths"*	40	29.0
Consequence of tourism – *comments about impacts from tourism related activities e.g., pathways, buildings; or tourists "just being here" with no specific impact mentioned*	38	27.5
Picking/touching - *people picking, taking or touching any part of the vegetation*	22	15.9
Trampling/off the track - *comments about trampling effects, people treading on vegetation or going off the track*	14	10.1
Erosion - *any comments about erosion or soil washing or falling away*	9	6.5
Other	15	10.9
Total	**134**	**100.0**

Note: 1. Respondents may record multiple responses.

3.5.3 Personal Impacts on Vegetation

Of the people who said they thought visitors *did* have an impact on the vegetation, nearly two thirds thought that they personally did not have any impact on the vegetation (Table A18). The responses to the sorts of impacts the respondents thought they personally had on the vegetation were generally imprecise with only 4 of the 28 comments referring to trampling effects (Table 6). The remainder of the comments did not mention a specific impact type. Nearly one half referred simply to human presence as an impact.

Table 6
Types of Impact Respondents Think They Have Had on the Vegetation

Impact Theme	Frequency	%
Human presence - *no specific impact mentioned e.g., "just by being here"*	13	46.4
Trampling - *comments about walking on the vegetation or off the formal path*	4	14.3
Small amount only - *respondent thinks the impacts are only minimal; may not be specific about the actual type of impact*	4	14.3
Other	7	25.0
Total	**28**	**100.0**

3.5.4 Concern About Impacts on the Vegetation

Respondents did not appear to be too concerned about the impacts of visitors on the vegetation, reflecting the high percentage of people who thought that visitors did not cause any impacts shown in Table A17. The figures presented in Table 7 below show that one third of respondents were not concerned at all by visitor impacts, and a further 21 per cent were only slightly concerned.

Table 7
Ratings of Concern About Visitor Impacts on the Vegetation

Response	Frequency	%	Mean	Std dev
Not at all concerned	113	33.6		
Slightly concerned	73	21.7		
Moderately concerned	84	25.0	2.31	1.21
Very much concerned	42	12.5		
Extremely concerned	16	4.8		
Missing	8	2.4		
Total	**336**	**100.0**		

Note: 1. Based on a 5 point scale where 1 = not at all concerned and 5 = extremely concerned

3.6 Visitors' Accounts of Inappropriate Behaviour

A total of 48 respondents, representing 14.3 per cent of the sample, admitted to either going off the formal path or picking some vegetation. Four people admitted to both forms of inappropriate behaviour.

3.6.1 Reporting on Their Own Behaviour

Respondents who admitted to stepping off the path or across any barriers represented 11.6 per cent of the sample (Table A19). The main reason given for stepping off the path was for photographic opportunities, followed by 'to have a look at something' and 'to touch something' (Table 8).

Table 8
Reason Given For Stepping Off the Path or Beyond Barriers

Reason	Frequency	%
Photography - *to take photos or video*	17	37.8
Look - *to have a look at something, or get a better view of something*	9	20.0
Touch - *wanted touch something e.g., soil, steam, water*	9	20.0
Other	10	22.2
Total	**45**	**100.0**

There were fewer respondents (3.9%, Table A20) who admitted to picking vegetation than going off the path (11.6%, Table A19) a third of whom said they did it 'without thinking' (Table 9). Other reasons given were to touch, or smell something, or to show something to another person. Four people admitted to both going off the path and picking some vegetation.

Table 9
Reason Why Respondent Picked Vegetation

Reason	Frequency	%
Mindless - *respondent didn't think about it*	4	33.3
Sensations - *to touch, smell, look at etc*	3	25.0
To show something to someone else	2	16.7
Other	3	25.0
Total	**12**	**100.0**

3.6.2 Reporting on Other People's Behaviour

Following the question regarding their own behaviour, respondents were then asked to report any inappropriate behaviour of other visitors they may have noticed. About one fifth of the sample said they saw other people go off the path (Table A21) (again, mainly for photography, Table A22), while a small percentage (6.3%) reporting seeing others picking the vegetation (Table A23). Interestingly, tour guides featured in eight out of the 19 comments about why respondents thought other people had picked vegetation (A24). When Tables A19 and A21 are compared it is interesting to note that almost twice as many people report "other's" deviant behaviour rather than their own (20.8% versus 11.6% positive responses respectively).

3.6.3 Respondents Who Admitted to Inappropriate Behaviour

People who admitted to going off the path or picking vegetation were grouped into a separate category, called 'deviators', for further analysis.

The pattern of country of origin of those who admitted some sort of inappropriate behaviour (Table A25) is similar to that of the overall sample (Table A1), except in the case of people from the UK where there is a much smaller percentage (12.5% as opposed to 22.9% in the overall sample).

Most of the people who admitted to inappropriate behaviour were male (Table A26) and fifty percent of the respondents fall in the under 35 years age categories (Table A27). The proportion of males in the 'deviators' category is greater than that of the rest of the sample (χ^2=11.254, df=1, p=.001), while the age of the 'deviators' was generally younger than the rest of the sample (χ^2=13.889, df=4, p=.008). Note that the age groups were collapsed into fewer groups to allow for the minimum of 5 cases in each cell for the chi-square test.

Surprisingly, the proportion of people who said they thought that visitors *did* have an impact on the vegetation was higher (nearly 40%, see Table 10) in the group admitting to inappropriate behaviour than the rest of the sample (25%). This result was statistically significant between the two groups (χ^2=5.648, df=1, p=.017)

Table 10
Do You Think Visitors Have Impacts on Vegetation?

Response	Frequency	%
No	26	54.2
Yes	19	39.6
Conditional Statement[1]	3	6.3
Total	**48**	**100.0**

Note: 1. See comments on conditional statements for Table A17

The results in Table 11, below, show that there was also a much higher percentage (57.9%) of 'deviators' who believed that they had a personal impact on the vegetation than those in the rest of the sample (24.2%). Again this was statistically significant (χ^2=7.708, df=1, p=.005).

Table 11
Do You Think You Had Any Impact on the Vegetation?

Response	Frequency	%
No	8	42.1
Yes	11	57.9
Total[1]	**19**	**100.0**

Note. 1. This sub group represents those who said 'yes' in Table 10 (above).

There was little difference in the responses by this group compared with the overall sample for the questions regarding their level of concern about visitor impacts (mean = 2.29 for the inappropriate behaviour group compared with 2.31 for the overall sample), and the proportion of the site they visited. There was, however, a higher awareness of rare and unique plants in the area, with 50 per cent of the 'deviators' stating that they *did* know about the existence of these plants, compared with less than one-third of the remainder of the respondent group (Table A28). The chi-square test shows there is a statistically significant difference between the groups (χ^2=16.678, df=1, p=.000).

3.7 Observations of Tourist Behaviour

During 10 days of fieldwork, 3274 observations of visitors were made at the two sites. Actual numbers of visitors to the sites are confidential, however our sample reflects an acceptable proportion of the total number of visitors. The total number of observations represents almost half (48.7%) of the total numbers of visitors to both sites during the study period. However, it was possible to observe the same person more than once (at different observation sites) and while this was unusual it means that the actual proportion of visitors observed will be slightly less than 48.7 per cent. Results from the observation data sheets are shown below.

Table 12
Field Observation Results

Observation	**Number**	
Total number of people observed	3274	
Total number of observation periods	290	
Total number of recorded deviations	43	
Percentage of deviations over total observations	1.3%	
		Percentage of total deviations (*n= 43)*
Gender		
Number of Adults	36	83.7
Number of Children	7	16.3
Number of Male Adults	19	44.2
Number of Female Adults	17	39.5
Number of Male Children	7	16.3
Number of Female Children	0	0.0
Age Group		
Under 10 years	4	9.3
10-20 years	3	7.0
21-30 years	10	23.3
31-40 years	10	23.3
41-50 years	5	11.6
51-60 years	7	16.3
60+ years	3	7.0
Missing	1	2.3
Language		
English speakers	16	37.2
Non-English speakers	23	53.5
Missing	4	9.3

The percentage of visitors who were recorded either going off the track or picking vegetation was low (1.3%) for the entire observation period. Most of these people were male, however when the split between gender and adults and children was made, the results indicate that female adults were almost as likely to 'deviate' as male adults. The majority (62.9%) of the people who were observed behaving inappropriately were estimated to be 40 years old or under, and more than half were identified as non-English speakers.

3.7.1 Type of Behaviour

Most (83.7%) of the 'deviators' were observed going off the track onto non-vegetated areas (Table 12). Very few people touched any vegetation either by brushing against it or trampling on it. Of the three people observed trampling on some vegetation, one was possibly on a manuka or kanuka shoot, one was on grass and the third was undetermined due to the observers' lack of botanical knowledge (Table A29). Only one person was observed picking vegetation during the observations.

Table 13
Type of Behaviour

Behaviour	Frequency	%
Off track – non-vegetated area	36	83.7
Off track – brushed vegetation	3	7.0
Off track – trampled vegetation	3	7.0
Picked vegetation – leaves	1	2.3
Picked vegetation – flowers	0	0.0
Total	**43**	**100.0**

3.7.2 Apparent Reason For Inappropriate Behaviour

'To look at features' and 'photography' were the two most common apparent reasons why people went off the track or picked vegetation (Table 13). Table A29 shows the breakdown by sites of the types of behaviour and apparent reasons for inappropriate behaviour.

Table 14
Apparent Reason for Inappropriate Behaviour

Reason	Frequency	%
To look at features	13	30.2
Photography	11	25.6
To touch soils, water etc	8	18.6
Other	8	18.6
Unsure	3	7.0
Total	**43**	**100.0**

Informal observations were also made, i.e., the observers also recorded other inappropriate behaviour whilst they were moving throughout the site. The informal records show similar patterns to the formal observations, with the bulk of the behaviour being off the track in non-vegetated areas.

Chapter 4

Discussion

4.1 Vegetation History in Relation to Tourist Impact

Following landscape change over time using the method of repeat photography has provided an effective means of investigating long-term changes in vegetation elsewhere, and has been widely used by ecologists and geographers (Veblen and Lorenz, 1991). Here, comparisons of past photographs of Waimangu and Waiotapu with current photographs show that areas of geothermal vegetation have remained relatively constant in extent and structure, whilst surrounding non-geothermal vegetation has undergone a rapid succession from areas denuded of vegetation to forest. The photos confirm that large numbers of tourists have been visiting these sites for the last century, but despite their continuous presence, there is no evidence of gross deterioration in geothermal vegetation. The condition of vegetation was not the prime focus of any photo, however. The crater area at Waiotapu is notable for the lack of recolonisation by vegetation of this barren area since at least the first photographs taken in the early part of the 20th century. We do not know if the continued absence of vegetation from this area is a result of physical limitations of this site or because of intensive tourist trampling.

4.2 Current Trampling Impacts

Informal tracks were not common at either Waimangu or Waiotapu. However, the soil penetration resistances of informal tracks and the lack of vegetation on these tracks suggest that those that do occur are commonly used. Informal tracks generally traversed areas with hotter soil temperatures than main tracks, with the hottest soils close to 100°C at 10cm depth. They therefore lead tourists into areas with higher relative danger than the main tracks. Vegetation height and cover was consistently lower on edge plots than on plots further away from tracks. This suggests that the effects of tracks extends into surrounding vegetation at least 30cm beyond each side of the track.

In several instances at Waimangu and Waiotapu, the start of a informal track coincided with an erosion channel caused by track runoff. Such runoff channels may unintentionally encourage tourists to move off the main track and explore, as their linear, unvegetated structure resembles the start of a formed track and give easy access to closer views. Better management of track runoff may mitigate effect.

The composition and structure of geothermal vegetation is strongly influenced by soil temperatures, and there is a generally characteristic sequence of species that occurs along a gradient of increasing temperature (Given, 1980; Burns, 1997). The vegetation encountered within plots on, and adjacent to, tracks at Waimangu was consistent with descriptions of geothermal vegetation on soils of similar temperature at Karapiti (Given,1980) and Te Kopia (Burns, 1997). Weed species on the edges of the main tracks were probably introduced as seeds

present in the material used to form and compact the main track. Although introduction of such species is generally to be avoided, in this situation the chances that these weeds will invade native geothermal vegetation is low as they are unlikely to be able to tolerate the high soil temperatures away from the refuge of the main track edge.

The mingimingi and prostrate kanuka shrub component of the vegetation association encountered at Waiotapu is similar to vegetation on slightly hotter soils described by Burns (1997) at Te Kopia. The high abundance of mingimingi here may indicate that the soils are extremely acidic (Clarkson and Clarkson, 1992). The complete lichen groundcover is, however, uncharacteristic of geothermal vegetation described elsewhere on these soil temperatures, in which a dense bryophyte turf is usual (Burns, 1997). Glime and Iwatsuki (1990; 1994) found that lichens of the genera Cladonia and Cladina are restricted to the drier areas of geothermal areas, with hot, moist soils being dominated by mosses. This suggests that soils of the main crater area at Waiotapu are drought prone and either receive little steam diffusing upwards from geothermally-heated groundwaters, and/or have a structure (e.g., low organic matter content, low porosity) that does not retain water from steam that does occur. Poor soil structure could have been caused by previous trampling.

In the mostly barren area around the Waiotapu main craters, islands of vegetation only occur on raised mounds in which soil has organic horizons. The soils of this barren area are compacted clays similar to the unmanaged track surfaces. Soil temperatures of the barren area are not high enough to exclude vegetation (average 28°C at 10cm depth). We therefore suggest that this area is a result of early visitors randomly exploring the main crater area. Their trampling may have removed vegetation and organic layers of the soil over wide areas, and compacted the subsoil into an impervious pavement on which vegetation recolonisation is unlikely on human timescales. Active restoration of this area may be possible if desired by managers.

4.3 Experimental Trampling

Soil penetration resistances on geothermal soils induced by 500 passes reached approximately 2000kPa. Not surprisingly, the mean penetration resistances of informal tracks at Waimangu and Waiotapu were even higher than this (3-4000kPa) suggesting substantially greater use of these tracks. Vegetation cover decreased rapidly with trampling, particularly impacting the bryophyte turf groundcover.

Comparison of the results obtained from geothermal vegetation here with similar studies on non-geothermal vegetation elsewhere suggest that this vegetation type is highly susceptible to trampling impacts. Liddle (1991) presents a table in which the resistances of different vegetation types to trampling are compared based on the number of passes required to reduce the vegetation cover by 50 per cent. Results range from 12-1475 passes. The cover of geothermal vegetation we studied was reduced by 50 per cent after approximately 175 passes. On this table, the susceptibility to trampling of geothermal vegetation is only surpassed by some arctic and alpine heaths, and a Scottish sand dune (Liddle, 1991). This ranking is supported by more recent research, e.g., Cole and Spildie (1998), in which a further two vegetation types in Montana had lower response to trampling than geothermal vegetation. This low resistance to trampling is

understandable in terms of the dominant life forms of geothermal vegetation. Yorks, et al., (1997) divided plants into 8 different life forms and ranked shrubs and thallophytes (mosses, liverworts, and lichens) as the second and third lowest in terms of their resistance to trampling.

Geothermal vegetation will also probably be slow to recover after trampling ceases in an area, although this was not specifically addressed in this study. Cole (1987) followed recovery after trampling in forest and grassland communities in Montana and suggested that there was a positive relationship between the productivity of a community and its ability to recover following disturbance by trampling. As geothermal vegetation has a low productivity, it will probably not recover quickly after trampling.

4.4 Tourists' Motivation for Visiting the Sites

Comments from the respondents indicated that geothermal sites are an important tourist attraction in the Rotorua region. For many, seeing these sites was the most important part of their holiday to the region, and was often the main reason for travelling to Rotorua. For almost 60 per cent of respondents, visiting a geothermal site was not a new phenomenon. Notwithstanding this fact, their satisfaction level remained high, as did the amount of effort they put in to visiting the entire site despite the length of time it often took to complete the visit. Safety and comfort may be another motivation for visiting the commercially operated sites, implied by the feelings of safety, trust and reliance about the management for ensuring risks are minimised and conveniences are provided (e.g., the café, shops, amenities, buses etc).

The main attraction on-site was visible geothermal activity such as bubbling water and mud, geysers, steam and hot springs. Although rare and unique, the vegetation did not feature strongly as an attraction at these sites. In fact, awareness of the unusual flora in the area was surprisingly low despite efforts by the operators to inform visitors about the vegetation. Of those who were aware that there were rare and unique plants on-site, the most effective methods of conveying information about the plants was through the brochures.

4.5 Tourists Perceptions of Their Impacts on the Vegetation

Most of the respondents thought that visitors did not have any impacts on the vegetation. This may be a reflection of the management structures in place, such as well-defined paths and barriers which restricts visitors from damaging the vegetation. Other important factors are the respondents' low level of awareness of rare plants in the area, and the insignificance of vegetation to the visitors' overall experience. These factors indicate that the vegetation is not at the forefront of visitors' concerns in general, and may mean that impacts on vegetation are almost irrelevant to them. This is confirmed in the measurement of the level of concern about flora impacts on-site where the mean score indicated that visitors were only 'slightly' to 'moderately' concerned. The result is the reverse of the original hypothesis that visitors would be very concerned about impacts, or would at least indicate a high level of concern from the social desirability effect (Singleton, et al., 1998). This effect is where people may give answers which they think are more socially acceptable than their true feelings about the issue. However, as

previous studies suggest, for some visitors to natural environments (particularly visitors with little or no prior experience in a similar environment) a small amount of impact or evidence of human presence is often preferable to none at all (Inglis, Johnson and Ponte, in press; Shelby, et al., 1988). The visitors to these commercially run geothermal sites may have chosen them because they have been altered by humans, and people visit them regularly so they are considered to be safe.

About one quarter of the respondents thought that there were impacts on the vegetation caused by visitors. However, the level of knowledge about the types of impacts that were likely to occur was fairly low. Most of the comments regarding the types of impacts were broad statements about the behaviour of visitors and impacts being inevitable wherever there is tourism. Very few respondents spoke about specific impacts such as damage through picking, trampling, or erosion. Even fewer people thought they had any personal impact on the vegetation during their visit, and again the types of impacts mentioned by respondents were generally vague.

4.6 Visitors' Behaviour On-site

4.6.1 Self-reported Behaviour

The proportion of people admitting to some form of inappropriate behaviour was higher than the expectations reached after discussions with the operators. However, the survey question asked respondents whether they stepped off the path or picked any vegetation and did not define exactly what was meant by 'off the path' . Conceivably, respondents may have many different interpretations of the boundaries of the formal pathway. In fact, the areas respondents mentioned during the course of the interviews were often different to the boundaries set for the purpose of the research. The definition used in the observation fieldwork specified that worn patches adjacent to the path were part of the formal pathway. The field observations were also based only in vegetated areas throughout the sites. Moreover, there were many areas throughout the sites that were devoid of vegetation and were not necessarily cordoned off by barriers or signs. Some of these areas, for example, allow visitors to walk around pools and up to the edge of streams. However, whether people were 'allowed' in the area was sometimes unclear. The apparent high percentage of inappropriate behaviour through the self-reporting method is, therefore, probably an overestimate of actual 'deviators' according to the area boundaries of the observation work.

While there may be differences in definitions, boundaries are identifiable by the respondents, and they recognise inappropriate behaviour. Those who admitted to going off the path did so to enable themselves to get a better view of an attraction either to take a photograph or just to see it better. These reasons were also given when respondents were asked why they thought other people had diverged off the path. The same two reasons appear in the results of the observations. Around one fifth of the respondents saw someone else off the path which again implies that 'appropriate' boundaries and behaviour exist in the mind of the visitor. As in the previous questions, picking vegetation was a low occurrence when survey participants were asked to report on other people's behaviour. It is interesting to note that the 'guide' was frequently mentioned as someone seen picking vegetation, however it is unclear as to whether respondents felt that this was acceptable.

People who admitted to inappropriate behaviour were mainly English speakers, with the exception of people from Germany. The proportions of respondents from the different countries were similar in spread to the overall sample except for people from the United Kingdom. Without knowing further details about these people, it is difficult to say why they were less likely to behave inappropriately than the rest of the sample. However, fewer people from the UK had been to a geothermal site before compared to the rest of the sample (χ^2=12.69329, df=1, p=.0017). Their behaviour may have been more cautious in the unfamiliar and potentially dangerous environment.

The significantly higher proportion of males who admitted to inappropriate behaviour is similar to previous studies that found males to be more likely to cause damage in some nature-based recreational activities (such as SCUBA diving) than females. In their study on divers on the Great Barrier Reef, Rouphael and Inglis (1995) found that males tended to be more danger-seeking and preferred to be closer to the natural attraction than females, and were therefore more likely to cause damage.

Perhaps one of the most surprising results was that more 'deviators' than non-deviators thought that both visitors and themselves have some sort of impact on the vegetation. They were also more likely to be aware of the rare and unique plants growing in the area. Divergence from the formal pathway or over the barriers appears to make people more aware of at least the possibility of damage. That they know about the rare and unique plants implies that they have read the brochures and signs to a greater extent than non-deviators, and may are seeking a more educational and participatory experience than merely a mindless wonder through the site.

4.6.2 Observed Behaviour

Interestingly, the gender of the 'deviators' observed in the field was just as likely to be male or female, unlike the self-reporting results. However, all of the children observed behaving inappropriately were male. It is difficult to say why there were fewer females in the survey results than the observations as this would require more information about the 'deviators' than that which could be derived from observations. The unsuccessful voucher method would have been ideal in this situation. There was only one voucher collected from a female respondent who had been observed across a ground-level barrier in a non-vegetated area, less than one metre from the pathway. In her survey responses, she did not think that she had gone off the track. It may be likely that females digressed from the path enough to be recorded in the observations, but not enough that they felt they were doing something wrong especially if 'danger-seeking' males were visible further off the track. Responses by females in the survey may also have been influenced by a desire to say they had behaved appropriately. This is known as the social desirability effect (Singleton, et al., 1998) where people give answers which may not be what they believe, but are thought to be a more socially acceptable response.

At least half of the deviations recorded in the field were people who did not speak English, or spoke it as a second language. Clearly this implies that the information in the brochures and signs is not entirely appropriate for some people. Although guide maps and brochures were provided in up to 16 different languages, most of the information and warning signs at the sites were in English. During the course of the interviews, some respondents asked what some of the signs meant.

Along the pathways at both sites attractions such as streams, craters, and lakes were brought to visitors' attention (through signs and the guide map). The main reason why people crossed barriers or digressed from the path was so they could see better or take photos of these attractions. This is consistent with the survey results (see above). The one person who picked some vegetation during the observations appeared to do so to have a closer look at the leaves.

The original hypothesis was that there would be fewer people self-reporting inappropriate behaviour than deviations observed in the field. The differences in the results of the two methods reflect the differences in the area of focus of the deviations, as mentioned above. That is, the research project was concerned with vegetated areas only while visitors reported on their behaviour throughout the entire site. Both the formal and informal observations also suggest that people are more likely to go off the track in a non-vegetated area. Therefore, while many of the non-vegetated or low-vegetated areas reported in the surveys were not covered in the observation work, deviations in these types of areas probably account for the majority of the difference in the results. As with any observation work, the results may have also been influenced by the observation techniques used by the researchers. That is, people may have altered their behaviour in the presence of the observer or other people, instead of behaving as they desired. This is referred to as the social facilitation effect (Baldwin and Baldwin, 1986), and while the researchers endeavoured to reduce this effect as much as possible, some influence is inevitable. However, the results are encouraging for the survey methodology, as they indicate that respondents were comfortable enough during the interview to provide genuine answers to sensitive questions.

Chapter 5

Conclusions

5.1 Geothermal Vegetation

Geothermal vegetation has been shown to be highly susceptible to trampling and the effects of trampling extend at least 30cm into the surrounding vegetation on either side of the track. However, track management at both Waimangu and Waiotapu appears to be adequate to prevent more than minimal damage to the surrounding vegetation.

Regeneration of geothermal vegetation is likely to be slow because of the low productivity of these species, particularly after track compaction, but high soil temperatures are unlikely to encourage the spread of weed species into the surrounding vegetation.

5.2 Management Implications

The results provide some implications for better management of the specific sites involved in the research, and of geothermal sites overall. Management of the study sites may need to look at:

- **Education**
  Improving visitor's learning about the vegetation and other components of the geothermal environmental through better signs, and including languages other than English; explaining better what is meant by inappropriate behaviour and increasing visitor's knowledge about potential impacts on the protected plants and soils; introduce other effective means of education not currently in use (e.g., more displays at the beginning of the walk, these can be interactive and focussed on attracting children's attention as well as adults, allowing them to touch leaves, soil samples etc).

- **Site Management**
  Plan for and provide structures which allow better views and photographic opportunities for visitors (of course this can only be done where it is safe to do so).

Overall, the study sites provided a positive, safe experience for visitors which has minimal environmental impact. Managers of other geothermal areas (particularly free access sites) should look at the management regimes within the operations studied here to help create better solutions for visitors' safety and comfort, while minimising the impacts on the fragile vegetation. If the goal of policy makers is sustainable regional development, decisions must made on the type of tourism which is promoted, and be focused on the long-term benefits (Travis, 1980) of protecting the environment while allowing access to such unique attractions. The sites studied in this research can be used as an example of how to achieve this goal.

5.3 Limitations of the Research

The research was conducted during the high season in Rotorua. Schools in New Zealand were on holiday, so this period was the peak of the domestic and international visitor movements in the country. The results, particularly the observations and reporting of other people's behaviour, are therefore a reflection of the 'worst case scenario' and should be read as such.

A gap in the survey information exists, as it was impossible to interview people on bus tours due to time constraints on their schedule. One of the operations received more tours than the other, and there is very little information available from the operators about these visitors. A separate survey would need to be designed to target these people.

There are, of course, some differences in the operations, which provide a slightly different type of experience for the visitor. The features within the sites are different, as is the coverage of vegetation and the number of other people visiting at peak times. However, for the purpose of this research the two sites were analysed as one type of experience in the Rotorua region. Tests for differences between the sites in relevant questions throughout the survey revealed little or no significant differences between the sites.

It is difficult to say whether either of the methods for recording inappropriate behaviour is more reliable than the other. Ideally, researchers should choose a method that is most appropriate to their research question. Further tests would need to be undertaken to confirm the reasons for differences in the results of the two methods in this study. More accurate measures of recording deviations on-site would be achievable through video surveillance however this is a time consuming and costly exercise that also raises ethical questions about the research methodology.

5.4 Further Research

The ability of geothermal vegetation to recover after trampling has stopped has not been studied. Further research would be needed to ascertain whether compacted soil prevents or alters the ability and composition of plants to establish.

To find out more about people who behave inappropriately at geothermal sites, a monitoring program should be set up at a variety of geothermal sites with different management regimes to establish more accurate information about people who go off the path or pick vegetation. Further investigation into the influences on people's behaviour such as the 'deviators' personal characteristics and more details about the physical attributes of the site will also be necessary. This work can then be linked with ecological studies to develop the carrying capacity (Wight, 1998) of particular sites to enable better management decisions about what level of impact is acceptable to both the users and management objectives.

Other research is suggested for the less managed sites in the Rotorua region, which are commonly used by local residents and some smaller tour operators. These sites have no control over the number of people using them, or the distribution of people within them. Some of these sites have informal paths criss-crossing the vegetation and may be of significant interest to research by DOC and other interested parties.

References

Baldwin, J.D., and Baldwin, J.I. (1986). *Behaviour Principles in Everyday Life* . Prentice Hall, NJ.

Beadel, S.M., MacKinnon, S.M., Shaw, W.B. (1996). Geothermal vegetation of the Bay of Plenty Region. Unpublished report, Wildlands Consultants, Rotorua.

Burns, B.R. (1997). Vegetation change along a geothermal stress gradient at the Te Kopia steamfield. *Journal of the Royal Society of New Zealand 27*: 279-294.

Clarkson, B.D. (1982). Waiotapu Scenic Reserve: main habitats and features. Unpublished report, Botany Division, DSIR, Rotorua.

Clarkson, B.D., Clarkson, B.R. (1992). Biological assessment of the geothermal areas on and adjacent to Taheke Papakainga Block. Unpublished report, Botany Division, DSIR, Rotorua.

Clarkson, B.D., Watt, V.J. (1986). Waimangu Scenic Reserve. Unpublished report, Botany Division, DSIR, Rotorua.

Cole, D.N. 1987: Effects of three seasons of experimental trampling on five Montana forest communities and a grassland in western Montana, USA. *Biological Conservation 40:* 219-244.

Cole, D.N., Bayfield, N.G. (1993). Recreational trampling of vegetation: standard experimental procedures. *Biological Conservation 63:* 209-215.

Cole, D.N., Spildie, D.R. (1998). Hiker, horse and llama trampling effects on native vegetation in Montana, USA. *Journal of environmental management 53:* 61-71.

Cowan, J. (1938). Rotorua: wonderland of the world. Rotorua Morning Post.

Devlin, P.J., Corbett, R., Peebles, C.J. (1995). (Eds). *Outdoor Recreation in New Zealand – a review and synthesis of research literature.* Department of Conservation/Lincoln University. Department of Conservation: Wellington.

Ecroyd, C. (1982). The botany and ecosystems of thermal areas. In: Keam, R.F. (Ed.), Geothermal systems: Energy, tourism, and conservation, pp. 53-56. Nature Conservation Council.

Given, D.R. (1976). Tropical pteridophytes of geothermal sites in the Taupo-Rotorua region. Botany Division, DSIR Report No. 144.

Given, D.R. (1980). Vegetation on heated soils at Karapiti, central North Island, New Zealand, and its relation to ground temperature. *New Zealand Journal of Botany 18*: 1-13.

Given, D.R. (1995). Geothermal vegetation: an assessment of botanical values of selected geothermal sites in the Taupo Volcanic Zone. Unpublished report, David Given Associates, Christchurch.

Glime, J.M., Iwatsuki, Z. (1990). Niche characteristics of *Cladonia* lichens associated with geothermal vents in Japan. *Ecological Research 5:* 131-141.

Glime, J.M., Iwatsuki, Z. (1994). Geothermal communities of Ponponyama, Hokkaido, Japan. *Journal of the Hattori Botanical Laboratory 75:* 133-147.

Glime, J.M., Iwatsuki, Z. (1997). Niche partitioning of plant taxa associated with geothermal vents at Wakoto, Hokkaido, Japan. *Journal of the Hattori Botanical Laboratory 82*: 123-141.

Hedenquist, J.W. (1986). Waiotapu geothermal field. In: Henley, R.W., Hedenquist, J.W., Roberts, P.J. (eds.). Guide to the Active Epithermal (Geothermal) Systems and Precious Metal Deposits of New Zealand. Gebruder Borntraeger, Berlin.

Huser, B. (1991). Geothermal resource management - a conservation perspective. Waikato Regional Council Technical Report No. 1991/2. Waikato Regional Council, Hamilton.

Inglis, G.J., V.Y. Johnson and F. Ponte. (in press). Crowding norms in marine settings: a case study of snorkelling on the Great Barrier Reef. *Environmental Management*.

Liddle, M.J. (1991). Recreation ecology: effects of trampling on plants and corals. *Trends in Ecology and Evolution 6:* 13-17.

McMillan, G. (1982). Tourism, recreation and reserves: the role of the Department of Lands and Survey. In: Keam, R.F. (ed.), Geothermal systems: energy, tourism, and conservation, pp. 57-63. Nature Conservation Council.

New Zealand Tourism Board (1996). International visitor survey: April 1995-March 1996. New Zealand Tourism Board; Wellington.

Noe, F. P., Hammitt, W. E. and Bixler, R. D. (1997). Park User Perceptions of Resource and Use Impacts Under Varied Situations in Three National Parks. *Journal of Environmental Management*, 49, 323-336.

Organisation for Economic Co-operation (OECD). (1980). *The impact of tourism on the environment*. General Report, OECD, Paris.

Parliamentary Commissioner for the Environment (PCE). (1997). *Management of the Environmental Effects Associated with the Tourism Sector*. Office of the Parliamentary Commissioner for the Environment, November.

Potter, S. 1997: Some like it hot. *New Zealand Geographic 33:* 78-86.

Price, M.F. (Ed.). (1996). *People and Tourism in Fragile Environments*. John Wiley and Sons, Chichester.

Rouphael, T. and Inglis, G. (1995) *The effects of qualified SCUBA divers on coral reefs*. CRC Reef Research Centre, Technical Report No. 4, CRC Reef Research Centre, Townsville, 39 p.

Saarinen, T.F., Seamon, D. and Sell, J.L. (Eds). (1984). *Environmental perception and behaviour an inventory and prospect*. Department of Geography, University of Chicago: Chicago.

Scott, B. (1992). *Waimangu. A Volcanic Encounter*. Waimangu Volcanic Valley; Rotorua.

Seward, T.M., Sheppard, D.S. (1986). Waimangu Geothermal Field. In: Henley, R.W., Hedenquist, J.W., Roberts, P.J. (Eds.). Guide to the Active Epithermal (Geothermal) Systems and Precious Metal Deposits of New Zealand. Gebruder Borntraeger, Berlin.

Shelby, B., and Harris, R. (1985). Comparing Methods for Determining Visitor Evaluations of Ecological Impacts: Site Visits, Photographs, and Written Descriptions. *Journal of Leisure Research*, 17 (1), 57-67.

Shelby, B., Vaske, J. J. and Harris, R. (1988). User Standards for Ecological Impacts at Wilderness Campsites. *Journal of Leisure Research*, 20 (3), 245-256.

Simmons, S.F., Keywood, M., Scott, B.J., Keam, R.F. (1993): Irreversible change of the Rotomahana-Waimangu hydrothermal system (New Zealand) as a consequence of a volcanic eruption. *Geology 21*: 643-646.

Singleton, R. A., Straits, B. C., and Straits, M. M. (1998). *Approaches to Social Research*. Oxford University Press, New York.

Smith, S.L.J. (1989). *Tourism Analysis: A Handbook*. Longman Scientific and Technical, Harlow, Essex.

Travis, A.S. (1980). The Need for Policy Action, in Organisation for Economic Co-operation and Development, *The Impact of tourism on the environment*. General Report, Paris.

Wight, P. (1998). Tools for sustainability analysis in planning and managing tourism and recreation in the destination, in C.M Hall and A.A. Lew (Eds) *Sustainable Tourism*, Addison Wesley Longman, New York, 75-91.

Yorks, T.P., West, N.E., Mueller, R.J., Warren, S.D. (1997). Toleration of traffic by vegetation: Life form conclusions and summary extracts from a comprehensive data base. *Environmental Management 21:* 121-131.

Appendix 1

Observation Sheet

Date	Location (Wx..)	closest Sign #	Start time	# Visitors (*in group size, eg 4/2/6/2/2/5*)	Total

Vis	Group Size	Off Track			Picked Vegetation			Apparent Reason	Location at site	Dist (m)	Status	Gender	Age	Language	Vouch #
#		Non-vegetated area	Brushed past plants	trampled plants ***	Leaves	flowers	other (*write*)	(*eg photo, look, touch soils, mi mi*)	*Record details eg. 2m to the left of #11 sign*	*Approx metres, eg 0.20, 2.5, 1.2*	Adult -A Child -C	Male – M Female- F	eg 10s, 20s, 60+	English –E Non-english - N	if any
1															
2															
3															
4															
5															

*** use one or some of these codes: s= scrub (eg.manuka/kanuka), b = bushes, g = grass, m = mosses, if not known write notes on what it looked like

Date	Location (Wx..)	closest Sign #	Start time	# Visitors (*in group size, eg 4/2/6/2/2/5*)	Total

Vis	Group Size	Off Track			Picked Vegetation			Apparent Reason	Location at site	Dist (m)	Status	Gender	Age	Language	Vouch #
#		Non-vegetated area	Brushed past plants	trampled plants ***	Leaves	flowers	Other (*write*)	(*eg photo, look, touch soils, mi mi*)	*Record details eg. 2m to the left of #11 sign*	*Approx metres, eg 0.20, 2.5, 1.2*	Adult -A Child -C	Male – M Female- F	eg 10s, 20s, 60+	English –E Non-english - N	if any
1															
2															
3															
4															
5															

*** use one or some of these codes: s= scrub (eg.manuka/kanuka), b = bushes, g = grass, m = mosses, if not known write notes on what it looked like

Appendix 2

Interviewer-Administered Questionnaire

INSTRUCTIONS TO INTERVIEWER: Read out questions in **bold**. Further instructions for you will be in *italics*. Please note that it is important that you:

- Read all *instructions*
- Read the questions **word for word**
- Write down exactly what the respondent says when answering your questions – word for word
- Do not suggest any answers to respondents – re-read the question to them if necessary

Hi my name is _____ and I am involved with a group from Lincoln University which is doing research on visitors to volcanic/geothermal sites. I have a brief survey here which takes about 5 to 10 minutes to complete. All your answers remain completely confidential and your identity will remain anonymous. Would you mind answering a few questions for me?

First, can I get you a cup of tea or coffee? (*Organise drink for respondent*)

(*Record*) Start Time: _____ am/pm Finish Time: _____am/pm

Interviewer Name: _____ Voucher # _____ (*if any*)

1. **What was your *main* reason for visiting this attraction today?**

   List the most important :

2. **We would like to know how important visiting a geothermal site during your stay in Rotorua is to you. Is it:** (*read out options below and tick response*)

❑ **a. The main reason I came to Rotorua, or**
❑ **b. Not the main reason I came here, but still an important part of my holiday in Rotorua, or**
❑ **c. Not something I originally planned on doing, but I came here anyway**

(*Write any other comments here*):

3. **Have you ever been to geothermal sites before this visit today? By this I mean natural places with geysers, steam, bubbling water and mud, hot springs etc not modified environments such as the Polynesian Spa in Rotorua.**

❑ No, this is my **first** visit to a geothermal area
❑ Yes→ (*If YES*), **about how often would you visit geothermal sites? Would it be** (*read list*):

- ❑ **Once a week or more**
- ❑ **Several times per month**
- ❑ **Several times per year, or**
- ❑ **Several times in my lifetime**

4. **Overall, how satisfied are you with your visit to this attraction today? Looking at this scale, which number best represents your level of satisfaction?**
(point to scale, read out list, and circle response):

1.....2.....3.....4.....5

Very Dissatisfied ..... Dissatisfied ..... Neither Satisfied nor Dissatisfied ..... Satisfied ..... Very Satisfied

And now we are going to talk more specifically about management issues.

5. Using the same scale as the previous question, please tell me how satisfied you were with the *walkways (circle response)*

1.....2.....3.....4.....5

(ii). Why do you think they are satisfactory / unsatisfactory?

6. **Using the same scale, can you now tell me how satisfied you were with the** ***barriers***

1.....2.....3.....4.....5

(ii). Why do you think they are satisfactory / unsatisfactory?

There are three types of signs at this attraction: safety, directional, and information.

7. **Using the same scale, can you now tell me how satisfied you were with the** ***Signs overall***

1.....2.....3.....4.....5

(ii). Why do you think the signs were satisfactory / unsatisfactory?

8. **Do you feel that there was any potential danger or risk to your health or safety from the natural environment at this attraction today?**

❑ No
❑ Yes

(If YES OR NO)
8a. Why did you feel that way? (*write responses below*)

9. Next I would like to know what natural features here today added most to your experience. Looking at this list of natural features (*point to list*)**, please rank them in order of importance to your experience from first (the most important) to fifth.** *(Read list and examples, then write number in box)*

#	*Category*
☐	Wildlife (birds and animals)
☐	Evidence of past geothermal activity (craters, terraces, soils, stalactites etc)
☐	Vegetation (trees, shrubs, bushes, ferns, mosses, lichens, algae etc)
☐	Visible geothermal activity (geysers, steam, bubbling water and mud, hot springs)
☐	Waterways (lakes, pools, streams)

10. Do you feel that people visiting this attraction have any impacts on the vegetation (that is, the trees, shrubs, mosses and other plant material) growing here?

❑ No → *(if NO, go to question 11)*

❑ Yes→ *(If YES)*, **what sort of impacts do you think are occurring?** (*write responses below*)

10a. Do you feel that you *personally* had any impact on the vegetation today?

❑ No

❑ Yes → *(If YES)*, **what sort of impacts do you think are occurring?** (*write responses below*)

11. Next I am interested in how much of the attraction you visited. Would you please show me on the map how far you walked today?

(*Show map on next page, record site #, or further details here*)

Site _____ OR (*tick*) ❑ visited the entire site

12. Remembering that your answers are completely confidential and anonymous, did you step off the formed path or beyond any barriers today?

❑ No

❑ Yes→ *(If YES)*, **what was your main reason for doing this?** *(write responses below)*

12a. Have you seen any other visitors do this today?

❑ No

❑ Yes → *record any comments*

13. Can you recall picking any flowers, leaves, mosses or other plant material today?

❑ No

❑ Yes → *(If YES)*, **what was your main reason for doing this?** *(write responses below)*

13a. Have you seen any other visitors do this today?

❑ No

❑ Yes → *record any comments*

14. To what extent are you concerned about impacts of visitors on the vegetation at this attraction? Looking at the list, would you say *(point to list and read out, then circle response)*:

1.....2.....3.....4 5

Not at all concerned... Slightly.....Moderately..... Very Much.. Extremely concerned

15. Are you aware that there are some rare and unique plants growing in this area?

❑ No

❑ Yes → *(If YES)*, **where did you learn about them?** *(write responses below)*

And now a few questions about you to make sure we have a representative sample of visitors...

16. Where do you normally live? (*please tick*)

- ❑ NZ (specify where) _____
- ❑ UK
- ❑ Germany
- ❑ Canada
- ❑ Taiwan
- ❑ The Netherlands
- ❑ Sweden
- ❑ Japan
- ❑ USA
- ❑ Denmark
- ❑ Australia
- ❑ Other (*please specify*)

17. What size is the group you are here with today? _____

18. Who are they? (*please tick the most appropriate box*)

- ❑ Visiting alone
- ❑ Partner/spouse
- ❑ Friends
- ❑ Family
- ❑ Friends and partner/spouse
- ❑ Friends and family
- ❑ Business associates
- ❑ Special interest group

19. Gender (*tick*)

❑ Male ❑ Female

20. What age group are you in? (*tick box*)

- ❑ 15 – 19
- ❑ 20 – 24
- ❑ 25 – 29
- ❑ 30 – 34
- ❑ 35 – 39
- ❑ 40 – 44
- ❑ 45 – 49
- ❑ 50 – 54
- ❑ 55 – 59
- ❑ 60 – 64
- ❑ 65 – 69
- ❑ 70 +

21. In terms of your overall attitude to the environment where would you place yourself on this scale? (*point to scale and read out*)

1	2	3	4	5
Not at all concerned	Slightly concerned	Moderately concerned	Very Much concerned	Extremely concerned

22. When not on holiday, do you participate in any outdoor recreation activities?

❑ No ❑ Yes (*write any comments below*)

23. Do you belong to any environmental groups?

❑ No ❑ Yes (*write any comments below*)

24. And finally, do you have any other comments you would like to make?
(*write responses here*):

Thank you very much for your time today, we really appreciate it. I hope you have an enjoyable holiday.

Record and transfer to cover page → Finish Time: _____am/pm

[INTERVIEWERS CHECKLIST:]

- ❑ Recorded Start and Finish Time on front of questionnaire?
- ❑ Recorded Interviewer name?
- ❑ Recorded Voucher Number if any?
- ❑ Attached Voucher if any?
- ❑ Responses are clear and legible (fix any notes and abbreviations up)?
- ❑ All responses are completed?
- ❑ Any extra notes are attached and have the relevant Question # written down?

Appendix 3

Full Data from Visitor Surveys

Table A1
Country of Origin

Country	Frequency	%
UK	77	22.9
New Zealand	71	21.1
Australia	44	13.1
Germany	37	11.0
The Netherlands	17	5.1
Canada	16	4.8
Denmark	11	3.3
Sweden	9	2.7
USA	8	2.4
Japan	2	0.6
Other	44	13.1
Total	**336**	**100.0**

Table A2
Group Size

Group Size	Frequency	%
1	20	6.0
2	175	52.1
3	47	14.0
4	51	15.2
5	18	5.4
6	10	3.0
8 or more	11	3.3
Missing	4	1.2
Total	**336**	**100.0**

Table A3
Group Type

Group Type	Frequency	%
Visiting alone	21	6.3
Partner/spouse	123	36.6
Friends	56	16.7
Family	89	26.5
Friends and partner/spouse	14	4.2
Friends and family	18	5.4
Special interest group/tour group	12	3.6
Business Associates	1	0.3
Missing	2	0.6
Total	**336**	**100.0**

Table A4
Gender

Gender	Frequency	%
Male	166	49.4
Female	166	49.4
Missing	4	1.2
Total	**336**	**100.0**

Table A5
Membership of an Environmental Group

Member	Frequency	%
No	262	78.0
Yes	58	17.3
Missing	16	4.8
Total	**336**	**100.0**

Table A6
When Not on Holiday, Do You Participate In Any Outdoor Recreation?

Response	Frequency	%
No	46	13.7
Yes	276	82.1
Missing	14	4.2
Total	**336**	**100.0**

Table A7
Main Reason for Visiting the Attraction

Main Reason	All visitors		Domestic		International	
	Frequency	%	Frequency	%	Frequency	%
To see geothermal sites – *includes any comments about geothermal activity, history, features.*	139	39.5	9	12.7	122	46.0
Sightseeing/Just passing by – *includes general comments about travelling in the area, 'something to do' etc.*	74	21.0	14	19.7	52	19.6
To show others – *showing other visitors including family, friends or tour group.*	48	13.6	31	43.7	13	4.9
Recommended – *it was recommended to them by other people or by books, visitor information guides, etc.*	48	13.6	4	5.6	38	14.3
Other	43	12.2	13	18.3	40	15.1
Total	**352**	**100.0**	**71**	**100.0**	**265**	**100.0**

Table A8
Importance of Visiting a Geothermal Site While in Rotorua

Response	Frequency	%
The main reason I came to Rotorua	166	49.4
Not the main reason, but still an important part of my holiday	140	41.7
Not something I originally planned to do, but I came here anyway	29	8.6
Missing	1	0.3
Total	**336**	**100.0**

Table A9
Previous Experience of Geothermal Sites

Response	Frequency	%
No	136	40.5
Yes	200	59.5
Total	**336**	**100.0**

Table A10
Frequency of Visits to Geothermal Sites

Response	Frequency	%
Once a week or more	1	0.5
Several times per month	2	1.1
Several times per year	14	7.0
Several times in my lifetime	183	91.5
Total	**200**	**100.0**

Table A11
Proportion of Site Visited

Approximate Proportion of the site	Frequency	%	Cumulative %
Shortest route (about 1/3)	32	9.5	9.6
About 2/3	58	17.3	26.9
The entire site	245	72.9	100.0
Missing	1	0.3	
Total	**336**	**100.0**	

Table A12
Satisfaction

Response	Frequency	%	Mean	Std dev
Very dissatisfied	0	0.0		
Dissatisfied	2	0.6		
Neither satisfied nor dissatisfied	7	2.1	4.62[1]	0.56
Satisfied	109	32.4		
Very satisfied	218	64.9		
Total	336	100.0		

Notes: 1. Based on a 5 point scale where 1 = very dissatisfied and 5 = very satisfied

Table A13
Feelings of Danger or Risk

Response	Frequency	%
No	308	91.7
Yes	22	6.5
Missing	6	1.8
Total	**336**	**100.0**

Table A14
Reasons Why People Did Not Feel There Was Any Danger to Their Health or Safety During Their Visit

Reason	Frequency	%
Management regime – *comments about the management of the site by either the operator or government agencies; comments on accessibility, information, signs, barriers, staff, etc.*	102	40.8
No reason – *the respondent did not feel there was any danger but could not give a reason why he/she felt that way.*	65	26.0
Visitor behaviour – *comments about visitors behaviour increasing or minimising risks e.g., "not if you stick to the paths".*	37	14.8
Other	46	18.4
Total	**246**	**100.0**

Table A15
Reasons Why People Did Feel There Was Some Danger to Their Health or Safety During Their Visit

Reason	Frequency	%
Dangers from the natural environment – *natural features of the site that the respondent felt may be dangerous e.g., steam, fumes, hot water.*	12	52.2
Management regime – *any comments to do with the management of the site making them feel unsafe*	3	13.0
Visitor behaviour – *comments about visitor behaviour being potentially dangerous.*	3	13.0
Other	5	21.7
Total	**23**	**100.0**

Table A16
Where People Learned About Rare and Unique Plants Growing in the Area

Where	Frequency	%
Brochure – *brochure from operator.*	34	30.9
Books – *any books including a guide book on-site, other guide books, travel books, botany books, etc.*	23	20.9
Other people – *other visitors, staff, etc.*	15	13.6
Saw them – *visitor thought they saw rare/unique plants.*	11	10.0
Guide – *personal guide, usually tour bus driver.*	10	9.1
Other	7	6.4
Missing	10	9.1
Total	**110**	**100.0**

Table A17
Perception of Visitor Impacts

Response	Frequency	%
No	213	63.4
Yes	83	24.7
Conditional statement[1]	38	11.3
Missing	2	0.6
Total	**336**	**100.0**

Note: 1. This category was developed for statements about impacts being conditional upon visitor behaviour and includes comments such as "no, as long as they stay on the paths" and "yes, if tourist numbers increase".

Table A18
Perception of Personal Impacts

Response	Frequency	%
No	53	63.9
Yes	26	31.3
Conditional statement[1]	3	3.6
Missing	1	1.2
Total[2]	**83**	**100.0**

Notes: 1. See comments on conditional statements for Table A17.
2. This sub-group represents those who said "yes" in Table A17 above.

Table A19
Respondents Who Stated They Stepped Off the Path

Response	Frequency	%
No	294	87.5
Yes	39	11.6
Missing	3	0.9
Total	**336**	**100.0**

Table A20
Respondents Who Stated They Picked Vegetation

Response	Frequency	%
No	319	94.9
Yes	13	3.9
Missing	4	1.2
Total	**336**	**100.0**

Table A21
Respondents Who Saw Other People Go Off the Path

Response	Frequency	%
No	255	75.9
Yes	70	20.8
Missing	11	3.3
Total	**336**	**100.0**

Table A22
Reason Why Visitors Stepped Off the Path or Over Barriers
(According to the Respondent)

Reason	Frequency	%
Photography – *photos or video.*	32	45.1
Touch – *wanted to touch something e.g., soil, steam, water.*	13	18.3
Look – *to have a look at something or get a better view of something.*	11	15.5
Other	15	21.1
Total	**71**	**100.0**

Table A23
Respondents Who Saw Other People Pick Vegetation

Response	Frequency	%
No	303	90.2
Yes	21	6.3
Missing	12	3.6
Total	**336**	**100.0**

Table A24
Reason Why Visitors Picked Vegetation
(According to Respondent)

Reason	Frequency	%
Guide – *the respondent saw the guide picking vegetation*	8	42.1
Other	11	57.9
Total	**19**	**100.0**

Table A25
Country of Origin of 'Deviators'

Country	Frequency	%
New Zealand	11	22.9
Australia	8	16.7
Germany	8	16.7
UK	6	12.5
The Netherlands	3	6.3
Canada	2	4.2
Denmark	2	4.2
Sweden	2	4.2
USA	2	4.2
Other	4	8.3
Total	**48**	**100.0**

Table A26
Gender of 'Deviators'

Gender	Frequency	%
Male	34	70.8
Female	13	27.1
Missing	1	2.1
Total	**48**	**100.0**

Table A27
Age Groups of 'Deviators'

Age Group	Frequency	%	Cumulative %
15-19	5	10.4	10.4
20-24	7	14.6	25.0
25-29	7	14.6	39.6
30-34	5	10.4	50.0
35-39	4	8.3	58.3
40-44	7	14.6	72.9
45-49	1	2.1	75.0
50-54	4	8.3	83.3
55-59	6	12.5	95.8
60+	2	4.2	100.0
Total	**48**	**100.0**	

Table A28
'Deviators' Awareness of Rare and Unique Plants

Response	Frequency	%
No	24	50.0
Yes	24	50.0
Total	**48**	**100.0**

Table A29
Location and Type of Inappropriate Behaviours Recorded in Formal Observations

Site	A1[1]	A2	A3	A4	A5	B1	B2	B3	B4
Total number of deviators	1	6	2	4	2	1	20	3	4
Off track – non-vegetated area	1 (look)	4 – photo (1), look (1), other (1), unsure (1)	1 (photo)	3 (photos)	2(other)		20 (photo = 5, touch = 4, look = 8, other = 3)	1 (other)	4 (touch)
Off track – brushed vegetation	1 (look)			1 (unsure)				1 (other)	
Off track – trampled vegetation		1 (photo)	1 (unsure)					1 (look)	
Description of plant trampled		manuka or kanuka shoot	grass					Unsure	
Picked vegetation – leaves						1 (look)			
Picked vegetation – flowers									

Note: 1. The sites have been divided into Operator A and Operator B